Report No. CG-D-07-91

AD-A247 090

# Resistance and Seakeeping Database for USCG 157 FT WLM

Roger H. Compton

U.S. Naval Academy
Division of Engineering and Weapons
Annapolis, Maryland 21402

DTIC
ELECTE
MAR 09 1992
S B D

FINAL REPORT
JULY 1991

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

DISTRIBUTION STATEMENT A
Approved for public release
Distribution Unlimited

Prepared for:

U.S. Coast Guard
Research and Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

92-05864

and

U.S. Department Of Transportation
United States Coast Guard
Office of Engineering, Logistics, and Development
Washington, DC 20593-0001

92 3 04 070

# NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

This report was directed and sponsored by the Coast Guard Research and Development Center. This report does not constitute a standard, specification or regulation.

SAMUEL F. POWEL, III
Technical Director
United States Coast Guard
Research & Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

Technical Report Documentation Page

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| CG-D-07-91 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| RESISTANCE AND SEAKEEPING DATABASE FOR USCG 157 FT WLM | July 1991 |
| | 6. Performing Organization Code |
| 7. Author(s) | 8. Performing Organization Report No. |
| Roger H. Compton | R&DC 16/91 |
| 9. Performing Organization Name and Address | 10. Work Unit No. (TRAIS) |
| U.S. Naval Academy<br>Division of Engineering and Weapons<br>Annapolis, Maryland 21402 | 11. Contract or Grant No. |
| | 13. Type of Report and Period Covered |
| 12. Sponsoring Agency Name and Address | Final Report |
| U.S. Coast Guard<br>Research and Development Center<br>1082 Shennecossett Road<br>Groton, Connecticut 06340-6096<br><br>Department of Transportation<br>U.S. Coast Guard<br>Office of Engineering, Logistics, and Development<br>Washington, D.C. 20593-0001 | 14. Sponsoring Agency Code |

15. Supplementary Notes

16. Abstract

EHP, sinkage and trim in calm water as functions of speed for the USCG 157 FT WLM buoy tender are derived from the results of 1/32 scale model tests in deep and shallow water. Long crested, head seas testing of the same model at three discrete speeds resulted in normalized response curves for pitch, heave, relative motion at Station 1 (of 10) and added resistance due to encountered waves.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| buoy tender<br>resistance<br>shallow water<br>seakeeping | Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161 |

| 19. Security Classif. (of this report) | 20. SECURITY CLASSIF. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| UNCLASSIFIED | UNCLASSIFIED | | |

Form DOT F 1700.7 (8/72) Reproduction of form and completed page is authorized

# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | * 2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 6.5 | square centimeters | $cm^2$ |
| $ft^2$ | square feet | 0.09 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8 | square meters | $m^2$ |
| $mi^2$ | square miles | 2.6 | square kilometers | $km^2$ |
| | acres | 0.4 | hectares | ha |
| | | **MASS (WEIGHT)** | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | | **VOLUME** | | |
| tsp | teaspoons | 5 | milliliters | ml |
| tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| $ft^3$ | cubic feet | 0.03 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.76 | cubic meters | $m^3$ |
| | | **TEMPERATURE (EXACT)** | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25. SD Catalog No. C13.10.286.

## Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | | **AREA** | | |
| $cm^2$ | square centimeters | 0.16 | square inches | $in^2$ |
| $m^2$ | square meters | 1.2 | square yards | $yd^2$ |
| $km^2$ | square kilometers | 0.4 | square miles | $mi^2$ |
| ha | hectares (10,000 $m^2$) | 2.5 | acres | |
| | | **MASS (WEIGHT)** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | | **VOLUME** | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 0.125 | cups | c |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| $m^3$ | cubic meters | 35 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.3 | cubic yards | $yd^3$ |
| | | **TEMPERATURE (EXACT)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |

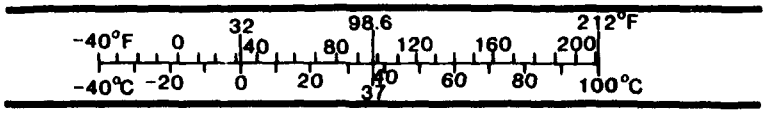


TABLE OF CONTENTS

Introduction ..... 1

Test Procedure ..... 1

Calm Water Test Results ..... 7

Seakeeping Results ..... 12

Data Base ..... 22

Acknowledgments ..... 22

LIST OF TABLES

1. 157 foot WLM Characteristics ..... 2

2. USCG 157' WLM: Regular, Long Crested, Head Sea Model Data ..... 13, 14

3. USCG 157' WLM: Data for Added Resistance Due to Waves ..... 19, 20

4. USCG 157' WLM: Irregular, Long Crested, Head Sea Model Data ..... 23

LIST OF FIGURES

1. ITTC Description of the 120'Towing Tank, U.S. Naval Academy Hydromechanics Laboratory ..... 3

2. FASTSHIP Lines (abbreviated) for 157' WLM ..... 4, 5

3. WLM Model Showing Outfitting and Ballast Arrangements ..... 6

4. WLM Model/Dynamometer Arrangement as used for Tests ..... 6

5. Effective Horsepower and Running Trim versus Ship Speed for 157' WLM in Deep Water ..... 8

6. Rise and Sinkage at the Perpendiculars versus Ship Speed for 157' WLM in Deep Water ..... 9

7. Effective Horsepower and Running Trim versus Ship Speed for 157' WLM in Shallow Water (h = 12' and h = 15') ..... 10

8. Rise and Sinkage at the Perpendiculars versus Ship Speed for 157' WLM in Shallow Water (h = 12' and h = 15') ..... 11

9. Normalized Pitch Response versus Model Encounter Frequency for 157' WLM at Three Model Speeds ..... 15

10. Normalized Heave Response versus Model Encounter Frequency for 157' WLM at Three Model Speeds ..... 17

11. Normalized Relative Motion at Station 1 (of 10) versus Model Encounter Frequency for 157' WLM at Two Model speeds ..... 18

12. Normalized Added Resistance due to Encountered Waves versus Model Encounter Frequency for 157' WLM at Three Model Speeds 24

---

APPENDICES

A. Calm Water Test Data ..... 25

B. Regular Wave Test Data ..... 46

Accession For
NTIS GRA&I ☑
DTIC TAB ☐
Unannounced ☐
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A-1

COPY INSPECTED

INTRODUCTION:

The data contained in this report were obtained for the U.S. Coast Guard under MIPR DTCG - 23 - 83-F-20033. A 1:32 scale model of the 157 foot coastal buoy tender (WLM) was tested in deep and shallow calm water, regular and irregular, long crested, head seas at the U.S. Naval Academy Hydromechanics Laboratory. All tests were conducted at model conditions corresponding to a full scale ship displacement of 471 long tons, zero static trim, six (6) foot draft, and a pitch gyradius of 37.45 feet (25% of $L_{WL}$). Calm water tests covered a range of model speeds corresponding to a full scale ship speed range of seven (7) to fifteen (15) knots. Seakeeping tests were run at two discrete model speeds which correspond to 8.2 knots and 12.2 knots for the full scale ship. In calm water, model speed, total model resistance, sinkage and trim were measured. In regular waves, model speed, total model resistance, pitch, heave, and relative bow motion at Station 1 were measured. In irregular waves, model speed, total model resistance, pitch, and heave were measured.

TEST PROCEDURE:

A 1:32 scale model was built according to lines provided by the U.S. Coast Guard by the U.S. Naval Academy's Technical Support Department, and tested in the 120 foot towing tank at the U.S. Naval Academy Hydromechanics Laboratory (NAHL). Characteristics for both the model and ship are given in Table 1. The 120 foot towing tank is described in Figure 1. The lines from which the model was fabricated (using FASTSHIP and the numerically controlled milling machine) are shown in Figure 2. Propeller tunnels, scaled from "as built" USCG drawings, were manually carved into the hull subsequent to the FASTSHIP/NC milling process. The model was constructed of six-pound, closed-cell foam, coated with a thin fiberglass shell.

Turbulence stimulation was accomplished using a single row of studs. The model was dynamically ballasted so that the model pitch gyradius (in air) was set to be 25% of the waterline length. Figure 3 shows the outfitted and ballasted model ready for mounting on the carriage. When mounted under the carriage in the 120 foot towing tank, the model was free to heave and pitch. Figure 4 shows the model mounted and aligned under the 120 foot tank carriage ready for testing. For regular wave testing, a nominally constant wave steepness, Hw/Lw, of 1/50 was maintained for Test 135 and 1/60 for the later testing, Test 322. The encountered wave was measured using a sonic probe mounted on the carriage. All test data were acquired using the NAHL computer-based data acquisition system.

TABLE 1

157 FOOT WLM CHARACTERISTICS

| | SHIP | MODEL ($\lambda$=32) |
|---|---|---|
| Length Overall | 157.0 ft. | 58.88 in. |
| Waterline Length | 150.1 ft. | 56.28 in. |
| Displacement[1] | 471.1 LT | 31.33 lb. |
| Wetted Surface | 4530.2 sq. ft | 637.06 sq. in. |
| LCG[2] | 2.1 ft. | 0.79 in. |
| Pitch Gyradius[3] | 37.5 ft. | 14.06 in. |

Notes:

1. Ship displacement for 59°F, salt water; model displacement for 68°F, fresh water.

2. LCG is referenced to amidships; positive values indicate G forward of amidships. Values in the table correspond to zero static trim.

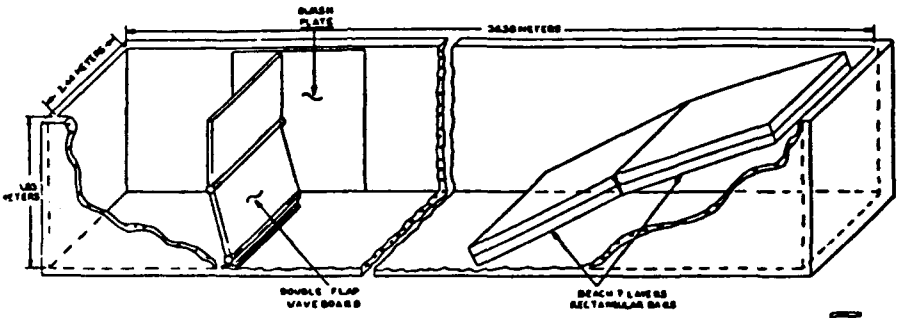
3. 25% of the waterline length.

INTERNATIONAL TOWING TANK CONFERENCE CATALOGUE OF FACILITIES

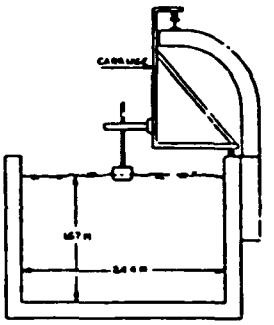
TOWING TANKS, SEAKEEPING AND MANOEUVRING BASINS

U. S. NAVAL ACADEMY HYDROMECHANICS LABORATORY
ANNAPOLIS, MARYLAND 21402
TELEPHONE: (301) 267-3361

36.6m TOWING TANK (1976)



120 FOOT TANK AND WAVEMAKER SYSTEM



DESCRIPTION OF CARRIAGE: unmanned

TYPE OF DRIVE SYSTEM AND TOTAL POWER: cable drive with 15 HP DC drive motor, digital speed control, manual/computer controlled

MAXIMUM CARRIAGE SPEED: 6 m/s (20 fps)

MODEL SIZE RANGE: 1m - 2m

TESTS PERFORMED: resistance in calm water and waves, seakeeping tests, various tests of ocean structures, hydrodynamic forces on submerged bodies, foils, etc., flow visualization

OTHER REMARKS: extensive software developed for standard test data base, shares computer with 128m towing tank, gravity towing capability

**FIGURE 1: ITTC Description of the 120' Towing Tank, U.S. Naval Academy Hydromechanics Laboratory**

NOTE: Twin propeller tunnels, extending from Sta. 8 to Sta. 10, were carved into the as-tested hullform, but are not shown in this FASTSHIP lines drawing.

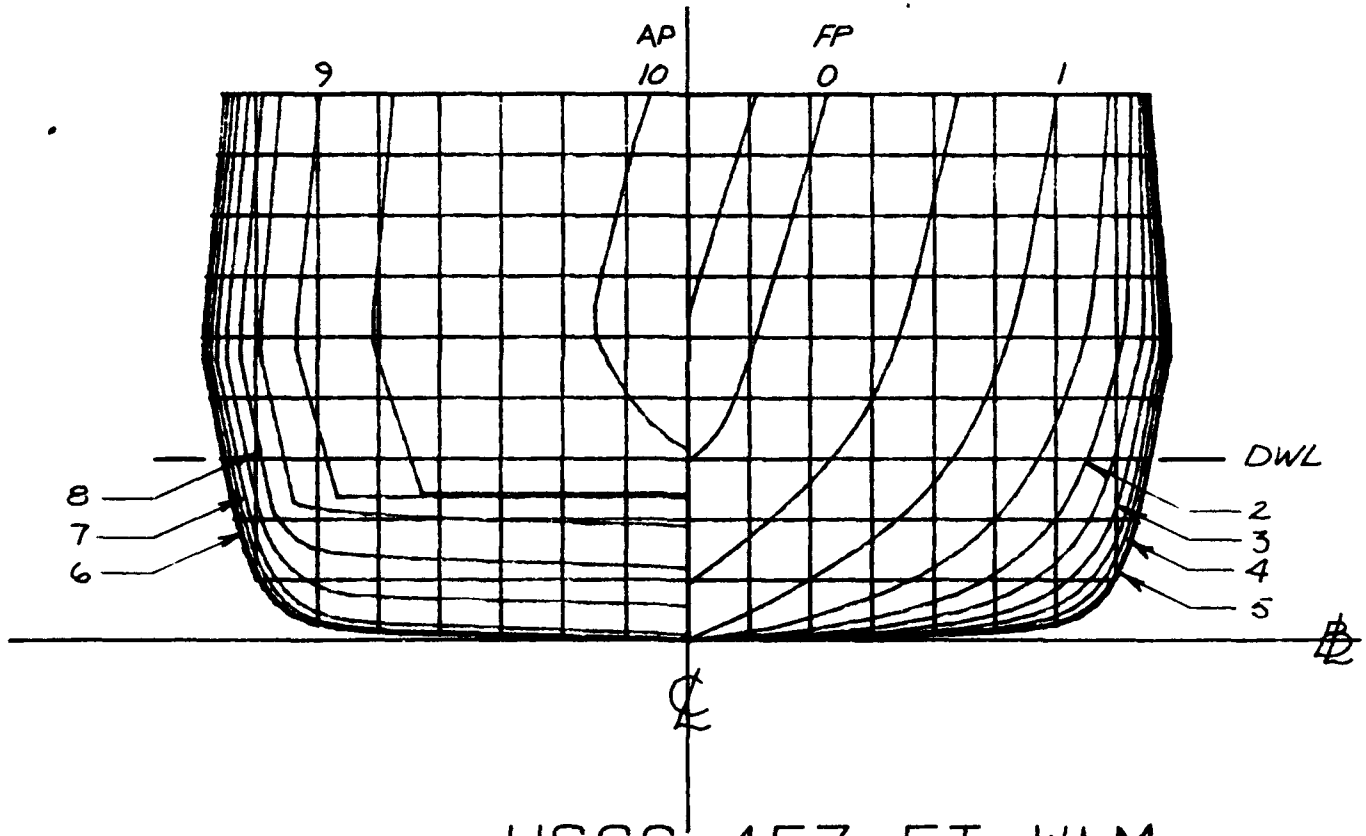
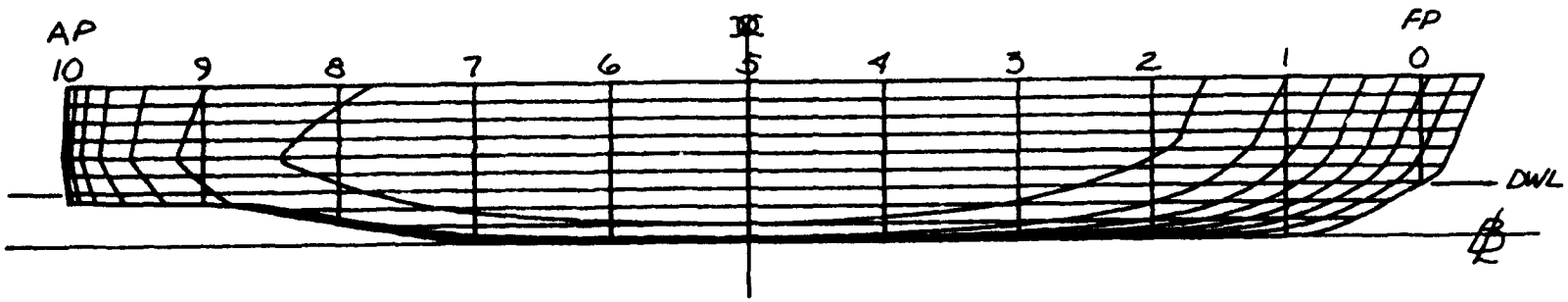



FIGURE 2: FASTSHIP Lines (abbreviated) for 157' WLM

NOTE: Twin propeller tunnels, extending from Sta. 8 to Sta. 10, were carved into the as-tested hullform, but are not shown in this FASTSHIP lines drawing.




USCG 157 FT WLM

15.0 ' STA; 2' WL; 2' BUTT

Scale 1: 250

FIGURE 2: FASTSHIP Lines (abbreviated) for 157' WLM

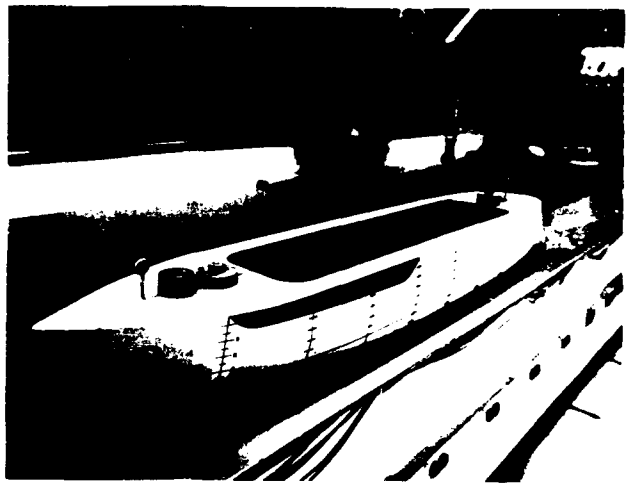


FIGURE 3: WLM Model Showing Outfitting and Ballast Arrangements

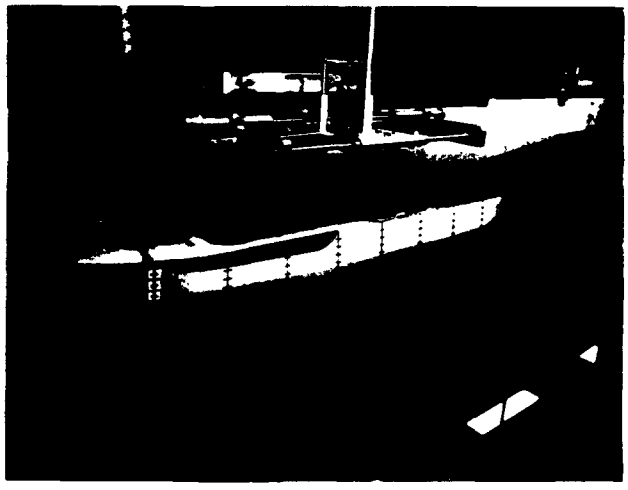


FIGURE 4: WLM Model/Dynamometer Arrangement As Used For Tests

CALM WATER TEST RESULTS:

A total of 48 runs were made in deep* water under test numbers 323 and 443 in December, 1989 and September, 1988 respectively. The cumulative tabulations and computer plots of these data are given in Appendix A. Blockage effects on model resistance in deep water were ignored since the ratio of tank cross-sectional area was 0.39%, well below the 0.5% rule of thumb. Employing Froude scaling, the ITTC 1957 frictional resistance coefficient, and a correlation allowance of 0.0005, these data were expanded, without any intermediate fairing, to effective horsepower (EHP) and running trim angle ($\tau$). EHP and $\tau$ are plotted against ship speed (Vs) in Figure 5. The open and solid symbols differentiate the data from the two totally independent tests performed more than a year apart. The repeatability appears to be excellent. Rise and sinkage at the perpendiculars are computed from the measured trim angle, the measured rise and sinkage at the towing point, and the model setup parameters. Throughout the speed range investigated, the ship squats with a slight bow down attitude as can be seen from Figure 6. Only the data from Test 323 are shown in Figure 6. Excessive data scatter on the rise/sinkage channel during Test 443 caused by tank water level changes and inconsistent rezeroing techniques was responsible for their omission from Figure 6.

The significant effects of operating in shallow water are shown in Figures 7 and 8. Both propulsive power requirements and ship attitudinal changes speed are drastically affected by water depth. For the trends shown in Figures 7 and 8, impervious, smooth, horizontal bottom conditions existed. Application of such trends to operation in waters where bottoms are not so easily defined should be made with caution. To facilitate comparison to other shallow water data or to analytical methods like the classical work of Schlichting, auxiliary scales of Froude number based on water depth ($F_{Nh} = v/\sqrt{gh}$), are shown on Figure 7. While trim angle and rise/sinkage at the perpendiculars appear well behaved at low speeds, considerable confusion develops at $F_{Nh} = 0.8$ for both depths tested. This behavior corresponds to the severe slope change in the EHP curve for both depths. Experimentation in shallow water at speeds approaching the critical speed (i.e., $F_{Nh} = 1.0$), is complicated by the fact that the hull generated wave system tends to be non-steady. That is, the widening of the Kelvin wave angle takes time which is not always available in a limited tank length. This is an area which needs experimental and theoretical attention.

---

*Tank water depth of 60 inches, which for this model corresponds to 160 feet for the ship.

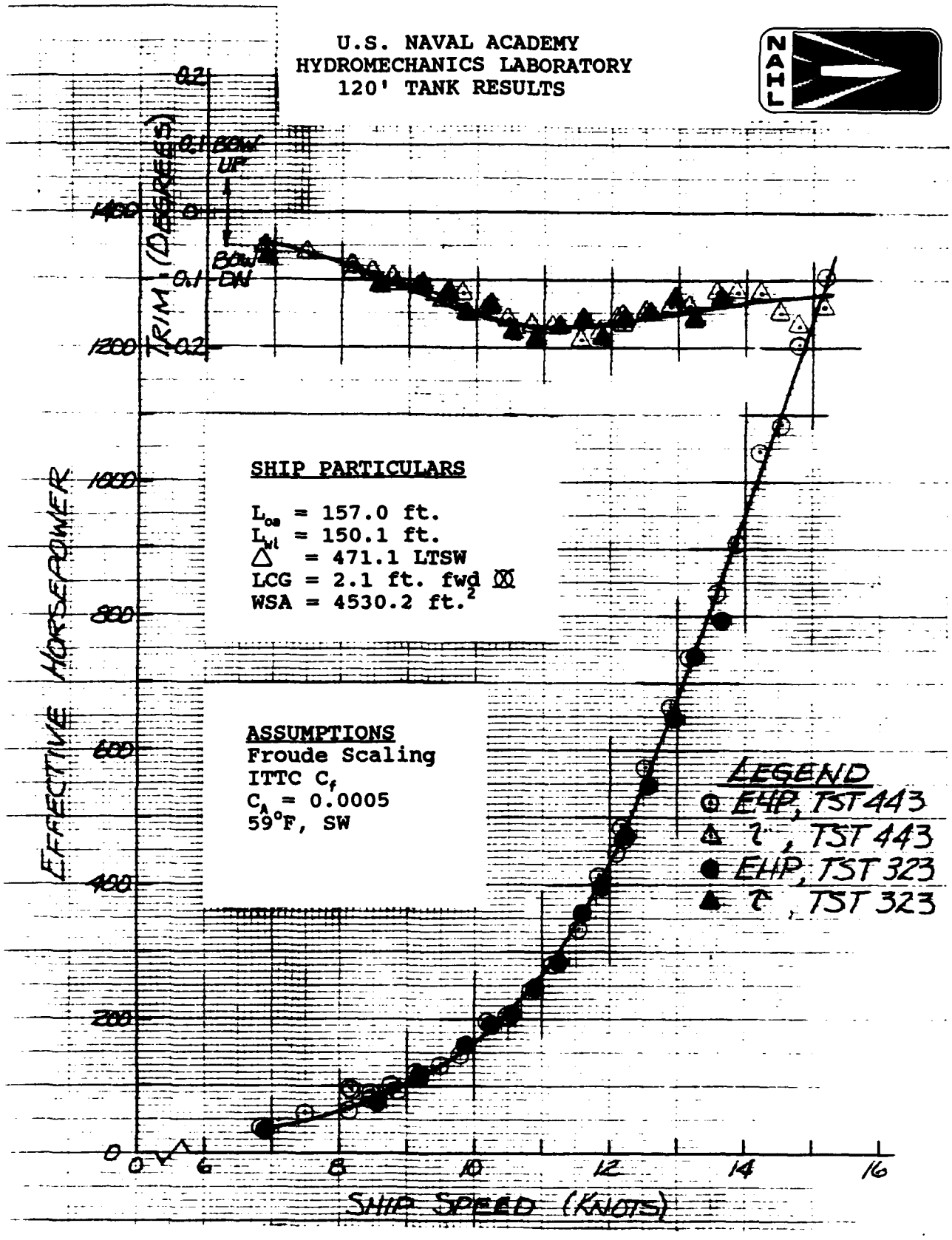



FIGURE 5: Effective Horsepower and Running Trim versus Ship Speed for 157' $_{WLM}$ in Deep Water

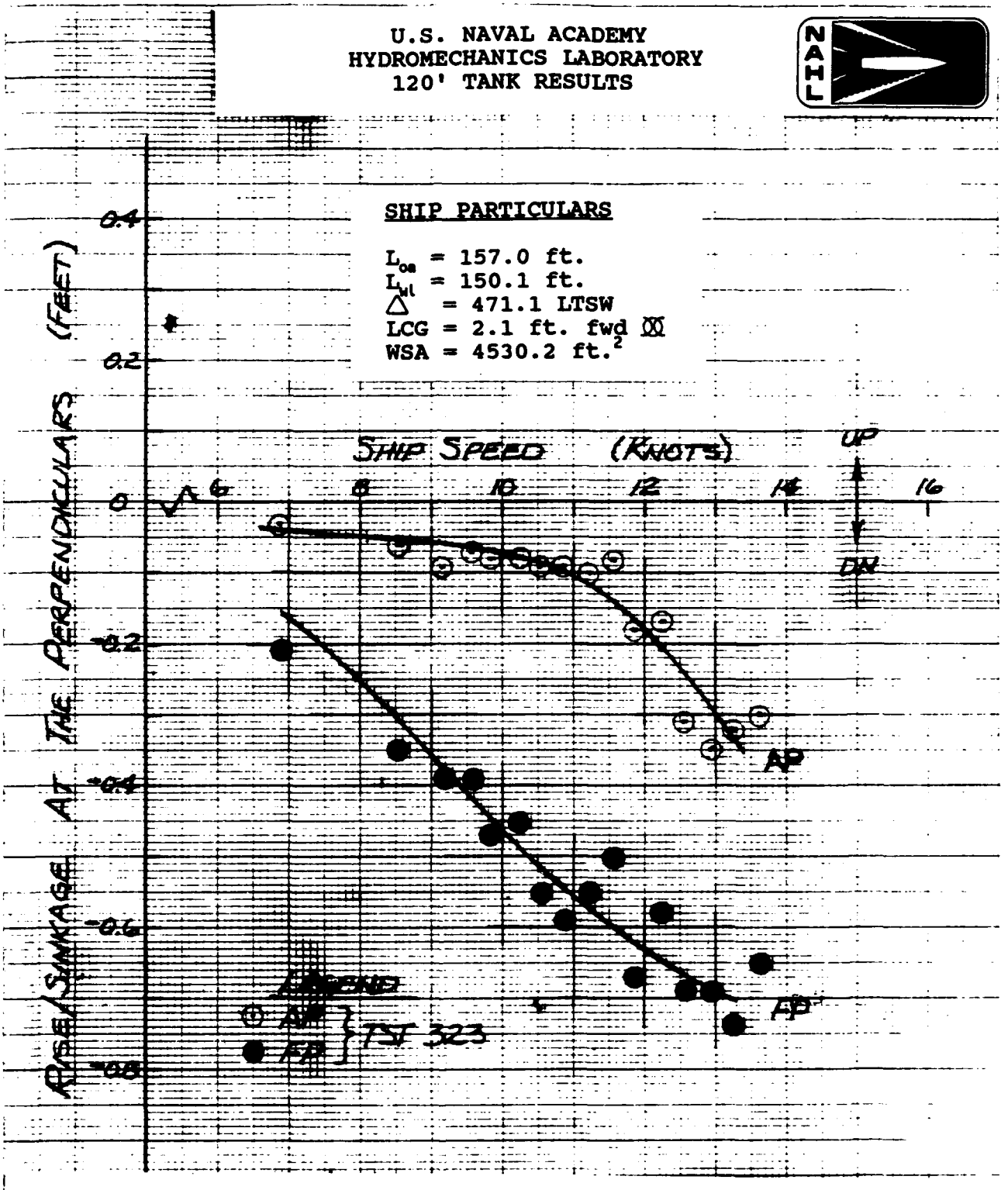



FIGURE 6: Rise and Sinkage at the Perpendiculars versus Ship Speed for 157' $_{WLM}$ in Deep Water

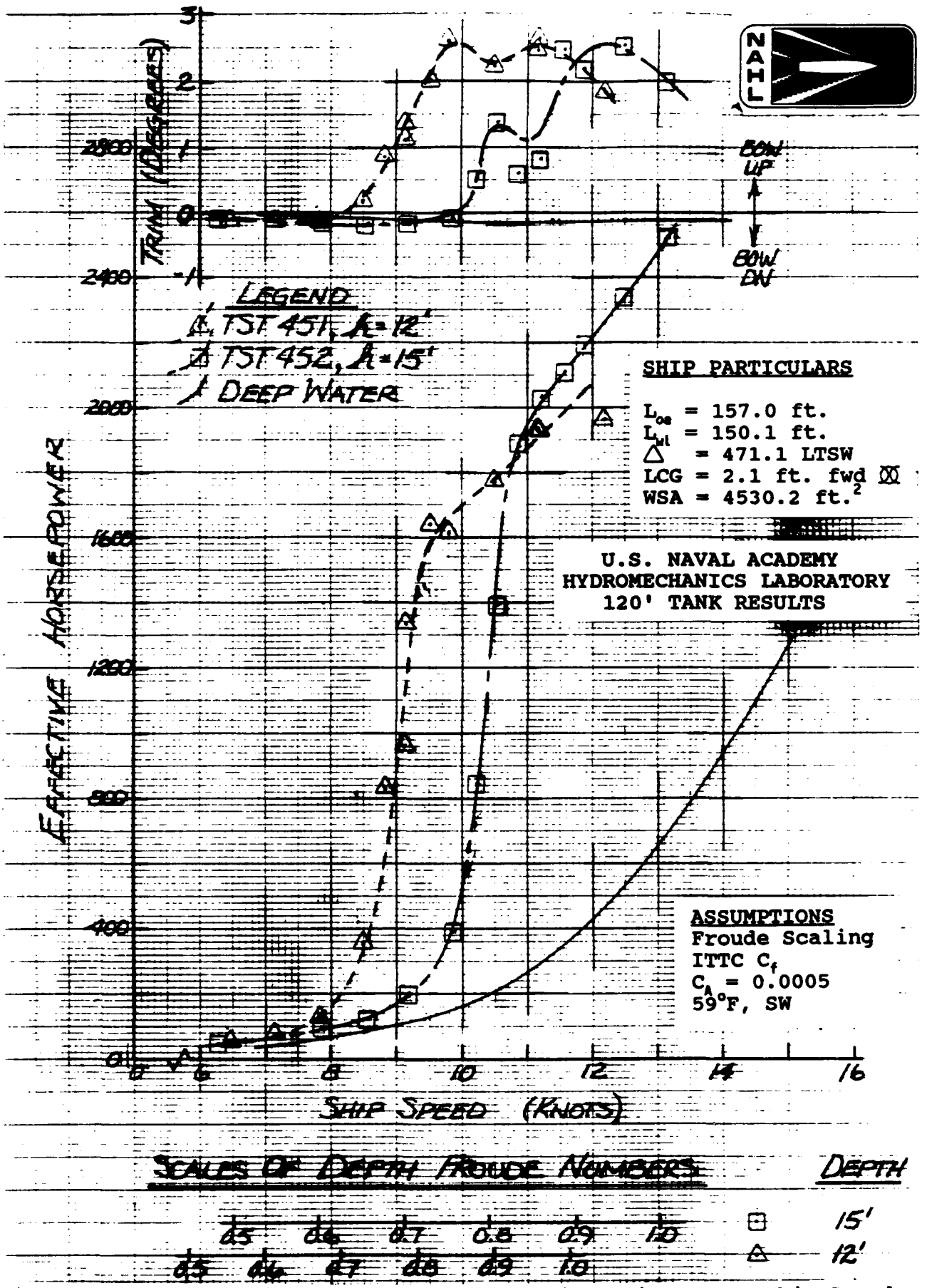



FIGURE 7: Effective Horsepower and Running Trim versus Ship Speed for 157' $_{WLM}$ in Shallow Water (h=12' and h=15')

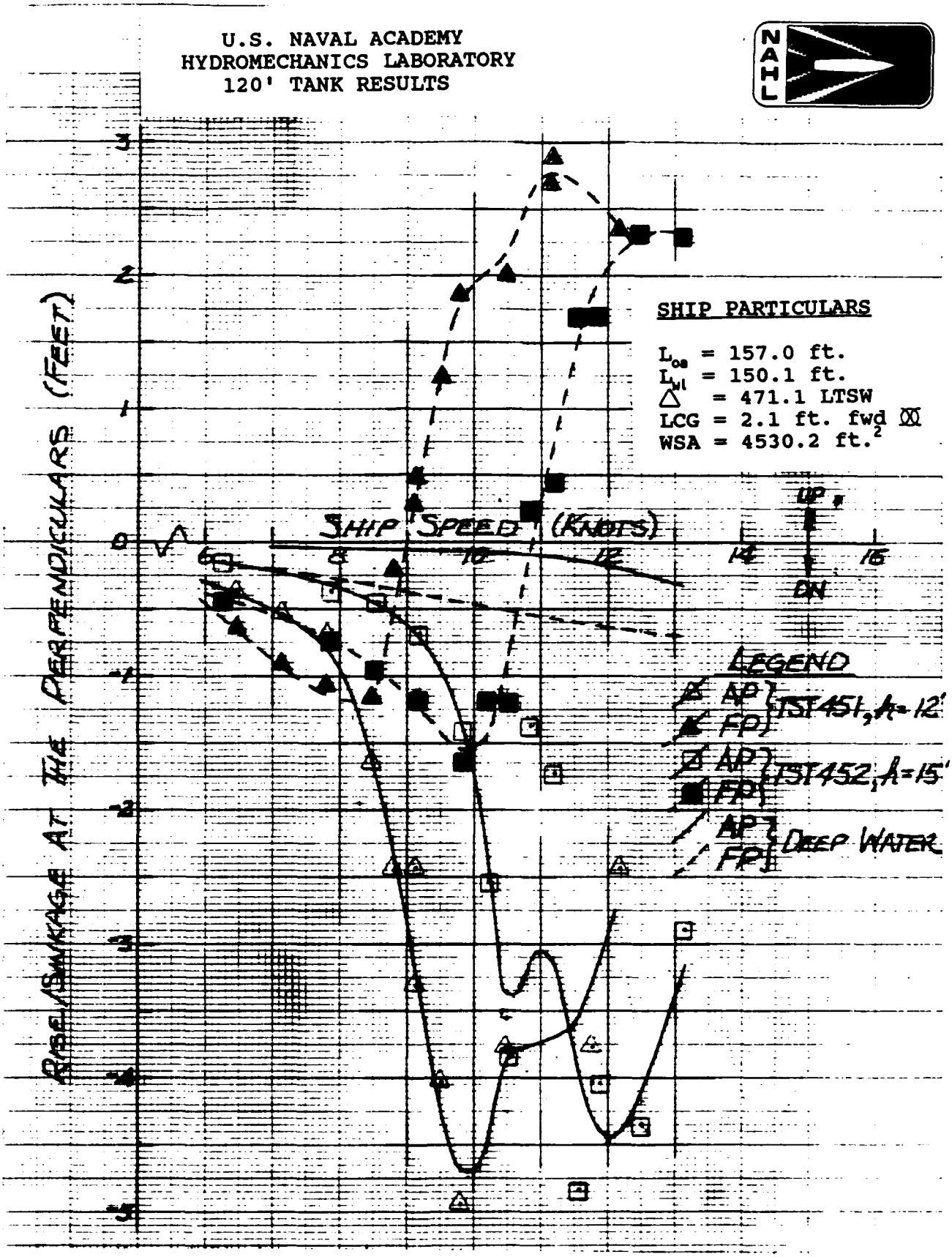



**FIGURE 8: Rise and Sinkage at the Perpendiculars versus Ship Speed for 157' $_{WLM}$ in Shallow Water (h=12' and h=15')**

SEAKEEPING RESULTS:

Table 2 is a summary of the measured, unsquared model data acquired during long crested, regular, head sea testing in the 120 foot towing tank. The model was ballasted as indicated in Table 1. The bifilar suspension method was used to set the longitudinal gyradius ($k_{zz}$).

Figure 9 is a plot of the normalized pitch response for three model speeds versus model encounter frequency. A pitch resonance around 1.34 Hz can be seen. No unusual behavior is noted from the pitch response curves. It is somewhat surprising that the peak of the highest speed response curve (□) does not exceed that of the middle speed curve (Δ). To develop ship scale values from Figure 9, the following are presented:

$$\left[\frac{2\theta(\text{deg})}{Hw\ (\text{ft})}\right]_{SHIP} = \left[\frac{2\theta(\text{deg})}{Hw\ (\text{ft})}\right]_{MODEL} \times \lambda^{-1}$$

$$\left[fe(\text{Hz})\right]_{SHIP} = \left[fe(\text{Hz})\right]_{MODEL} \times \lambda^{-1/2}$$

$$\left[V(\text{knots})\right]_{SHIP} = \left[v(\text{fps})\right]_{MODEL} \times \lambda^{1/2}/1.688$$

where $\lambda = L_{SHIP}/L_{MODEL}$

TABLE 2
USCG 157' WLM
REGULAR, LONG CRESTED, HEAD SEA MODEL DATA

120' TANK $\lambda$ = 32 $k_{zz}$ = 0.25 Lpp

TEST #135, SUBTEST #1; FW @ 65°F
$\overline{v_m}$ = 2.45 fps. Nominal Hw/Lw = 1/50 ⊙

| $fe_m$ (Hz) | $Lw_m$ (ft) | 2θ/Hw (deg/ft) | 2z/Hw (ft/ft) | RBM @ STA 1/Hw (ft/ft) |
|---|---|---|---|---|
| 1.479 | 5.1 | 39.50 | 0.514 | 3.01 |
| 0.559 | 22.4 | 15.20 | 0.960 | 0.23 |
| 0.776 | 13.9 | 25.63 | 0.910 | 0.43 |
| 0.936 | 10.4 | 32.40 | 0.840 | 0.72 |
| 1.106 | 8.0 | 41.35 | 0.740 | 1.18 |
| 1.287 | 6.3 | 46.37 | 0.618 | 1.99 |
| 1.479 | 5.1 | 38.60 | 0.484 | ---- |
| 1.679 | 4.2 | 22.29 | 0.326 | 3.20 |
| 1.888 | 3.6 | 8.64 | 0.172 | 1.89 |

TEST #135, SUBTEST #2; FW @ 65°F
$\overline{v_m}$ = 3.65 fps Nominal Hw/Lw = 1/50 □

| | | | | |
|---|---|---|---|---|
| 0.613 | 22.4 | 14.66 | 0.989 | 0.30 |
| 0.775 | 16.2 | 21.61 | 0.962 | 0.32 |
| 0.955 | 12.0 | 30.33 | 0.934 | 0.59 |
| 1.152 | 9.1 | 41.35 | 0.890 | 1.27 |
| 1.365 | 7.1 | 49.80 | 0.892 | 2.67 |
| 1.595 | 5.7 | 42.19 | 0.768 | 4.13 |
| 1.836 | 4.6 | 25.36 | 0.417 | 4.30 |
| 2.094 | 3.9 | 9.35 | 0.139 | 3.09 |

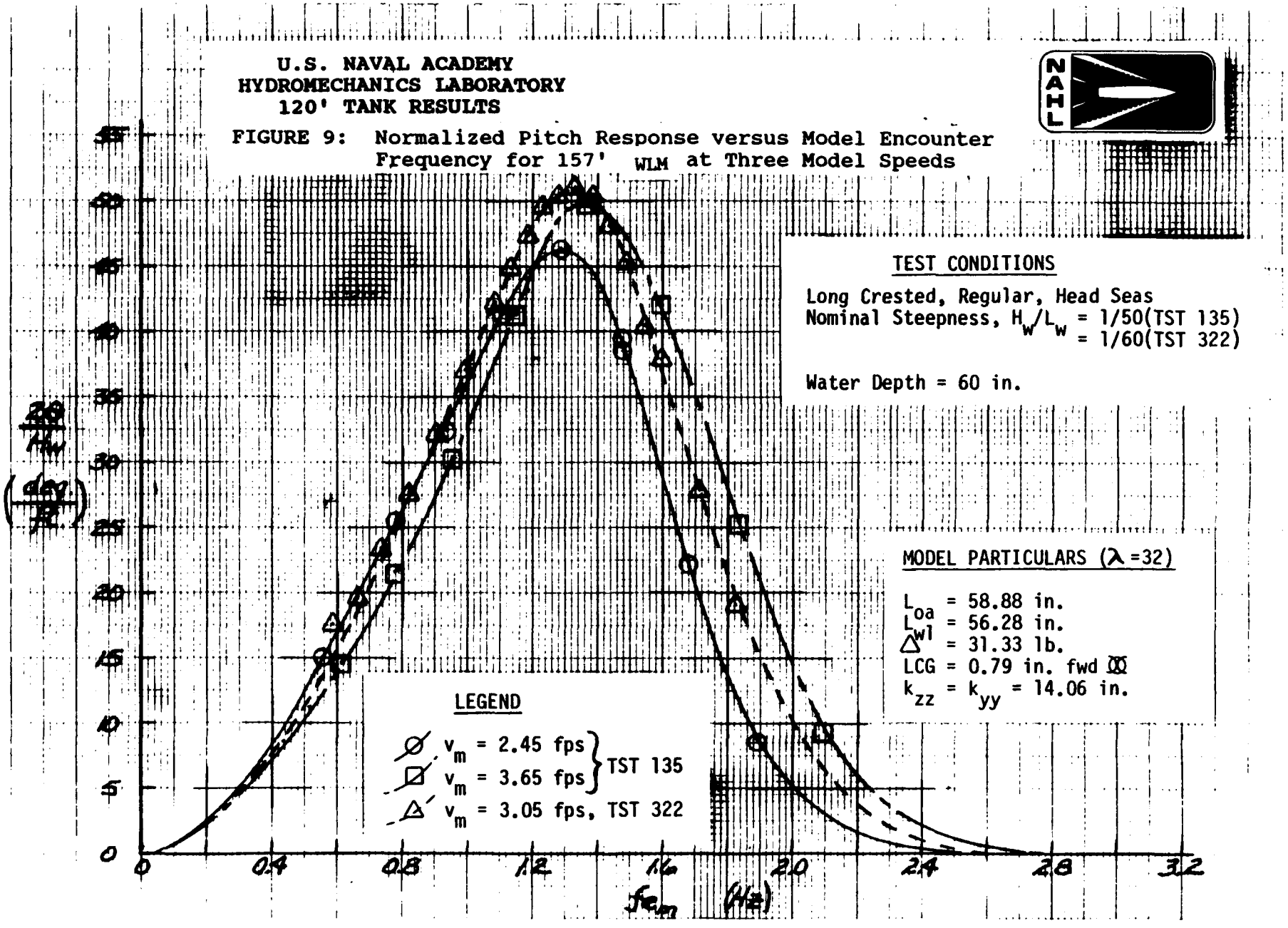
TABLE 2
USCG 157' WLM
REGULAR, LONG CRESTED, HEAD SEA MODEL DATA

120' TANK $\lambda$ = 32 $k_{zz}$ = 0.25 Lpp

TEST #322, SUBTEST #1; FW @ 63.5°F
$\bar{V}_m$ = 3.05 fps Nominal Hw/Lw = 1/60 Δ

| $fe_m$ (Hz) | $Lw_m$ (ft) | 2θ/Hw (deg/ft) | 2z/Hw (ft/ft) | RBM @ STA 1/Hw (ft/ft) |
|---|---|---|---|---|
| 1.597 | 5.1 | 37.82 | 0.584 | DATA NOT ACQUIRED |
| 0.586 | 22.4 | 17.52 | 0.973 | |
| 0.661 | 19.0 | 19.67 | 0.977 | |
| 0.820 | 13.9 | 27.66 | 0.917 | |
| 0.993 | 10.4 | 37.01 | 0.869 | |
| 1.183 | 8.0 | 47.33 | 0.814 | |
| 1.383 | 6.3 | 50.50 | 0.760 | |
| 1.822 | 4.2 | 19.08 | 0.284 | |
| 1.488 | 5.7 | 45.28 | 0.690 | |
| 1.281 | 7.1 | 50.40 | 0.782 | |
| 1.332 | 6.7 | 51.09 | 0.783 | |
| 1.435 | 6.0 | 48.06 | 0.723 | |
| 1.232 | 7.5 | 49.60 | 0.804 | |
| 1.086 | 9.1 | 42.19 | 0.834 | |
| 0.905 | 12.0 | 32.09 | 0.902 | |
| 0.738 | 16.2 | 23.47 | 0.953 | |
| 1.708 | 4.6 | 27.87 | 0.416 | |
| 1.134 | 8.5 | 44.94 | 0.829 | |
| 1.543 | 5.4 | 40.50 | 0.624 | |

Locked in surge, sway, yaw, and roll. Water depth = 5 ft.


U.S. NAVAL ACADEMY
HYDROMECHANICS LABORATORY
120' TANK RESULTS
FIGURE 9: Normalized Pitch Response versus Model Encounter Frequency for 157' WLM at Three Model Speeds
NAHL
TEST CONDITIONS
Long Crested, Regular, Head Seas
Nominal Steepness, $H_w/L_w$ = 1/50(TST 135)
= 1/60(TST 322)
Water Depth = 60 in.
MODEL PARTICULARS (λ=32)
$L_{oa}$ = 58.88 in.
$L_{wl}$ = 56.28 in.
Δ = 31.33 lb.
LCG = 0.79 in. fwd ⊠
$k_{zz} = k_{yy}$ = 14.06 in.
LEGEND
$v_m$ = 2.45 fps
$v_m$ = 3.65 fps } TST 135
$v_m$ = 3.05 fps, TST 322
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
$f_{e_m}$ (Hz)

If nondimensional format for normalized pitch response is preferred,

$$\left[\text{Pitch/Wave Slope}\right] = \left[\frac{2\theta\,(\text{deg})}{Hw(ft)}\right] \times \frac{Lw(ft)}{360}$$

where wave slope is $\pi$ Hw/Lw (radians)

Figure 10 is a plot of the normalized heave response for the same three model speeds versus model encounter frequency. The curves show a consistent trend of increasing motion as speed increases. The apparent resonant frequency in heave is about 1.38 Hz. All curves decay to zero reasonably at high frequencies. To develop ship scale values from Figure 10, the following is presented:

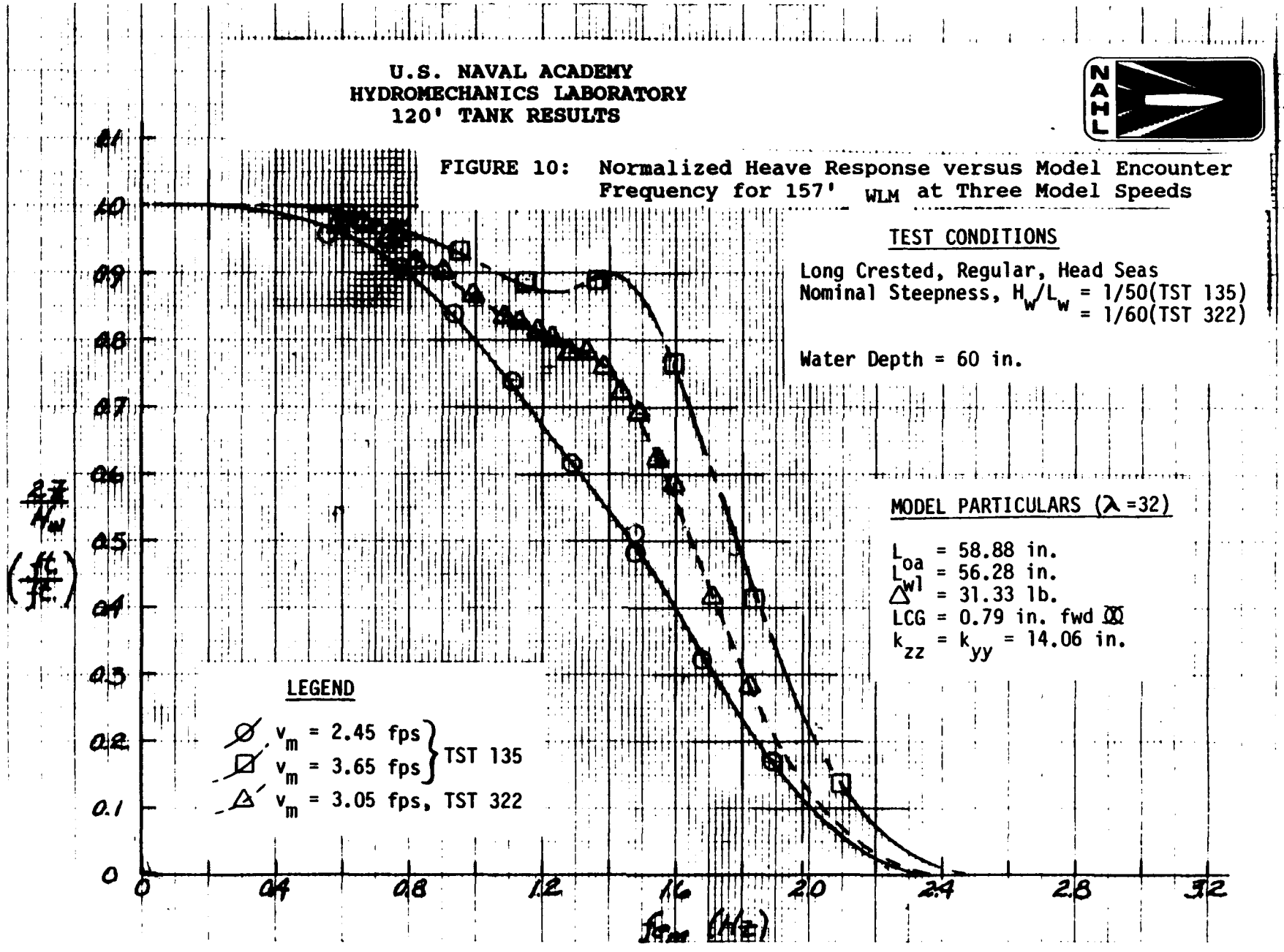
$$\left[\frac{2z(ft)}{Hw(ft)}\right]_{SHIP} = \left[\frac{2z(ft)}{Hw(ft)}\right]_{MODEL}$$

Encounter frequency and speed scale as given earlier.

Figure 11 is a plot of the normalized relative vertical motion between the hull and the water surface at Station 1, which, for this ship, is the forward end of the bulwark cutout in way of the buoy work deck. Unlike the previous two responses (pitch and heave), which are absolute motions, relative bow motion, RBM, is in effect, dynamic local freeboard and local draft. This response is observed visually as the model moves down the tank using the vertical scale affixed to the side of the model at Station 1 (see Figures 3 and 4). RBM data were acquired for the lowest and highest model speed conditions only. The normalized response curves shown in Figure 11 are reasonable in shape and magnitude. To develop ship scale values for normalized RBM response, proceed exactly as for heave; i.e.,

$$\left[\frac{RBM(ft)}{Hw\ (ft)}\right]_{SHIP} = \left[\frac{RBM(ft)}{Hw\ (ft)}\right]_{MODEL}$$

Table 3 contains the parameters and data used to compute the normalized added resistance due to waves in regular, long crested, head seas at each of three model speeds. The values of the still water total model resistance coefficient for each of the speeds were read from a curve faired through $C_{Tm}$ data from Tests 323 and 443 (Appendix A). Figure 12 is a plot of the normalized added resistance due to waves at each of three model speeds versus model encounter frequency. The data scatter is considerably greater for this response than for pitch or heave shown earlier, especially near the peak responses. No apparent order based on model speed can be deduced from Figure 8. The curves peak between 1.5 Hz and 1.7 Hz - roughly between the absolute motions (pitch and heave) and the relative bow motion. To develop ship scale values from Figure 12, the following is presented:


U.S. NAVAL ACADEMY
HYDROMECHANICS LABORATORY
120' TANK RESULTS
NAHL
FIGURE 10: Normalized Heave Response versus Model Encounter Frequency for 157' WLM at Three Model Speeds
TEST CONDITIONS
Long Crested, Regular, Head Seas
Nominal Steepness, $H_w/L_w$ = 1/50(TST 135)
= 1/60(TST 322)
Water Depth = 60 in.
MODEL PARTICULARS (λ=32)
$L_{oa}$ = 58.88 in.
$L_{wl}$ = 56.28 in.
Δ = 31.33 lb.
LCG = 0.79 in. fwd ⊠
$k_{zz}$ = $k_{yy}$ = 14.06 in.
LEGEND
$v_m$ = 2.45 fps
$v_m$ = 3.65 fps } TST 135
$v_m$ = 3.05 fps, TST 322
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2

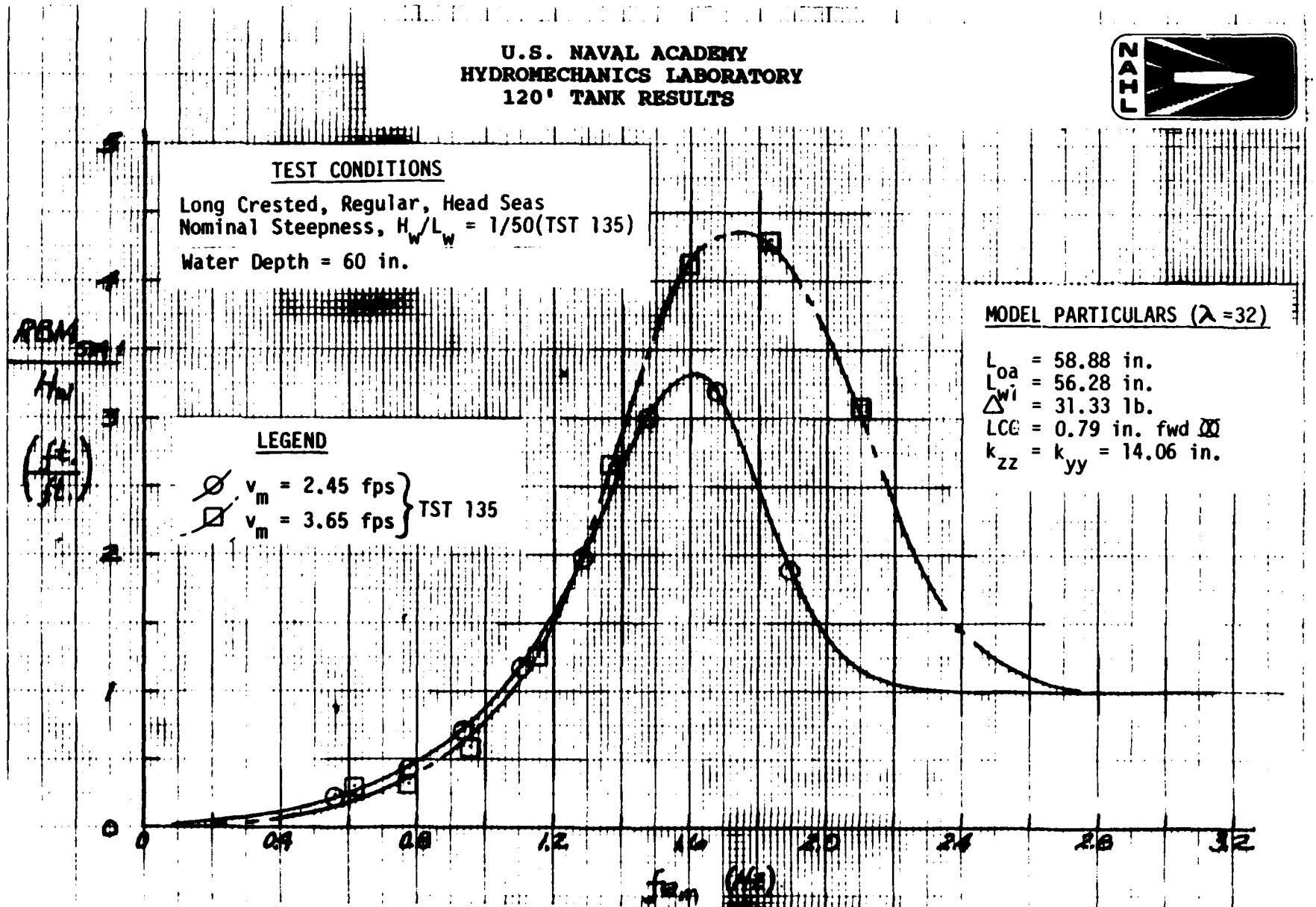



FIGURE 11: Normalized Relative Motion at Station 1 (of 10) versus Model Encounter Frequency for 157' $_{WLM}$ at Two Model Speeds

TABLE 3
USCG 157' WLM

DATA FOR ADDED RESISTANCE DUE TO WAVES

120' TANK  $\lambda$ = 32  $k_{zz}$ = 0.25 Lpp

@ 2.45 fps, $C_{Tmsw}$ = 5.682 x $10^{-3}$, 65°F ⊙
WSA = 4.424 sq. ft.  $\rho_m$ = 1.9373 lb.sec$^2$ /ft$^4$

| $fe_m$ (Hz) | $C_{Tmw}$ x10 | $v_m$ (fps) | $C_{TAw}$ x10 | Hw (ft) | $R_{Awm}$ (lb) | $R_{Awm}/Hw_m^2$ (lb/ft$^2$) |
|---|---|---|---|---|---|---|
| 1.479 | 9.255 | 2.453 | 3.573 | 0.072 | 0.092 | 17.772 |
| 0.559 | 5.568 | 2.451 | - | 0.330 | - | - |
| 0.776 | 8.881 | 2.453 | 3.199 | 0 302 | 0.082 | 0.904 |
| 0.936 | 8.748 | 2.449 | 3.066 | 0.188 | 0.079 | 2.230 |
| 1.106 | 9.575 | 2.449 | 3.893 | 0.142 | 0.100 | 4.962 |
| 1.287 | 10.860 | 2.448 | 5.178 | 0.110 | 0.133 | 10.990 |
| 1.479 | 10.940 | 2.451 | 5.258 | 0.088 | 0.135 | 17.479 |
| 1.679 | 8.726 | 2.449 | 3.044 | 0.078 | 0.078 | 12.859 |
| 1.888 | 7.102 | 2.446 | 1.420 | 0.066 | 0.036 | 8.358 |

@ 3.05 fps, $C_{Tmsw}$ = 6.641x$10^{-3}$, 63.5°F △
WSA = 4.424 sq. ft.  $\rho_m$ = 1.9376 lb.sec$^2$/ft$^4$

| | | | | | | |
|---|---|---|---|---|---|---|
| 1.597 | 9.355 | 3.054 | 2.714 | 0.076 | 0.108 | 18.783 |
| 0.586 | 7.932 | 3.038 | 1.291 | 0.320 | 0.051 | 0.499 |
| 0.661 | 7.771 | 3.055 | 1.130 | 0.294 | 0.045 | 0.523 |
| 0.820 | 6.087 | 3.065 | - | - | - | - |
| 0.993 | 7.961 | 3.047 | 1.320 | 0.184 | 0.052 | 1.551 |
| 1.183 | 8.782 | 3.057 | 2.141 | 0.138 | 0.086 | 4.503 |
| 1.383 | 9.439 | 3.054 | 2.798 | 0.100 | 0.112 | 11.185 |
| 1.822 | 7.597 | 3.054 | 0.956 | 0.076 | 0.038 | 6.616 |
| 1.488 | 9.425 | 3.054 | 2.784 | 0.090 | 0.111 | 13.740 |
| 1.281 | 9.466 | 3.055 | 2.825 | 0.118 | 0.113 | 8.116 |
| 1.332 | 10.010 | 3.055 | 3.369 | 0.116 | 0.135 | 10.015 |
| 1.435 | 9.763 | 3.054 | 3.122 | 0.098 | 0.125 | 12.995 |
| 1.232 | 8.800 | 3.055 | 2.159 | 0.124 | 0.086 | 5.617 |
| 1.086 | 8.351 | 3.054 | 1.710 | 0.156 | 0.068 | 2.809 |
| 0.905 | 7.138 | 3.054 | 0.497 | 0.206 | 0.020 | 0.468 |
| 0.738 | 6.921 | 3.055 | 0.280 | 0.268 | 0.011 | 0.156 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1.708 | 7.762 | 3.055 | 1.121 | 0.072 | 0.045 | 8.650 |
| 1.134 | 8.455 | 3.055 | 1.814 | 0.150 | 0.073 | 3.225 |
| 1.543 | 9.277 | 3.055 | 2.636 | 0.090 | 0.105 | 13.018 |

@3.65 fps $C_{Tmsw} = 8.675 \times 10^{-3}$, 65°F □
WSA = 4.424 sq.ft. $\rho m = 1.9373 \frac{lb\ sec^2}{ft^4}$

| $fe_m$ (Hz) | $C_{Tmw}$ x$10^3$ | $v_m$ (fps) | $C_{TAw}$ x10 | Hw (ft) | $R_{Awm}$ (lb) | $R_{Awm}/Hw_m^2$ ($lb/ft^2$) |
|---|---|---|---|---|---|---|
| — | | | | | | |
| 0.613 | 9.087 | 3.650 | 0.412 | 0.330 | 0.024 | 0.216 |
| 0.775 | 10.220 | 3.658 | 1.545 | 0.274 | 0.089 | 1.180 |
| 0.955 | 11.060 | 3.651 | 2.385 | 0.212 | 0.136 | 3.031 |
| 1.152 | 11.410 | 3.653 | 2.735 | 0.162 | 0.156 | 5.960 |
| 1.365 | 12.810 | 3.650 | 4.135 | 0.126 | 0.236 | 14.870 |
| 1.595 | 12.480 | 3.656 | 3.805 | 0.104 | 0.218 | 20.150 |
| 1.836 | 11.050 | 3.650 | 2.375 | 0.084 | 0.136 | 19.216 |
| 2.094 | 10.220 | 3.653 | 1.545 | 0.080 | 0.088 | 13.805 |

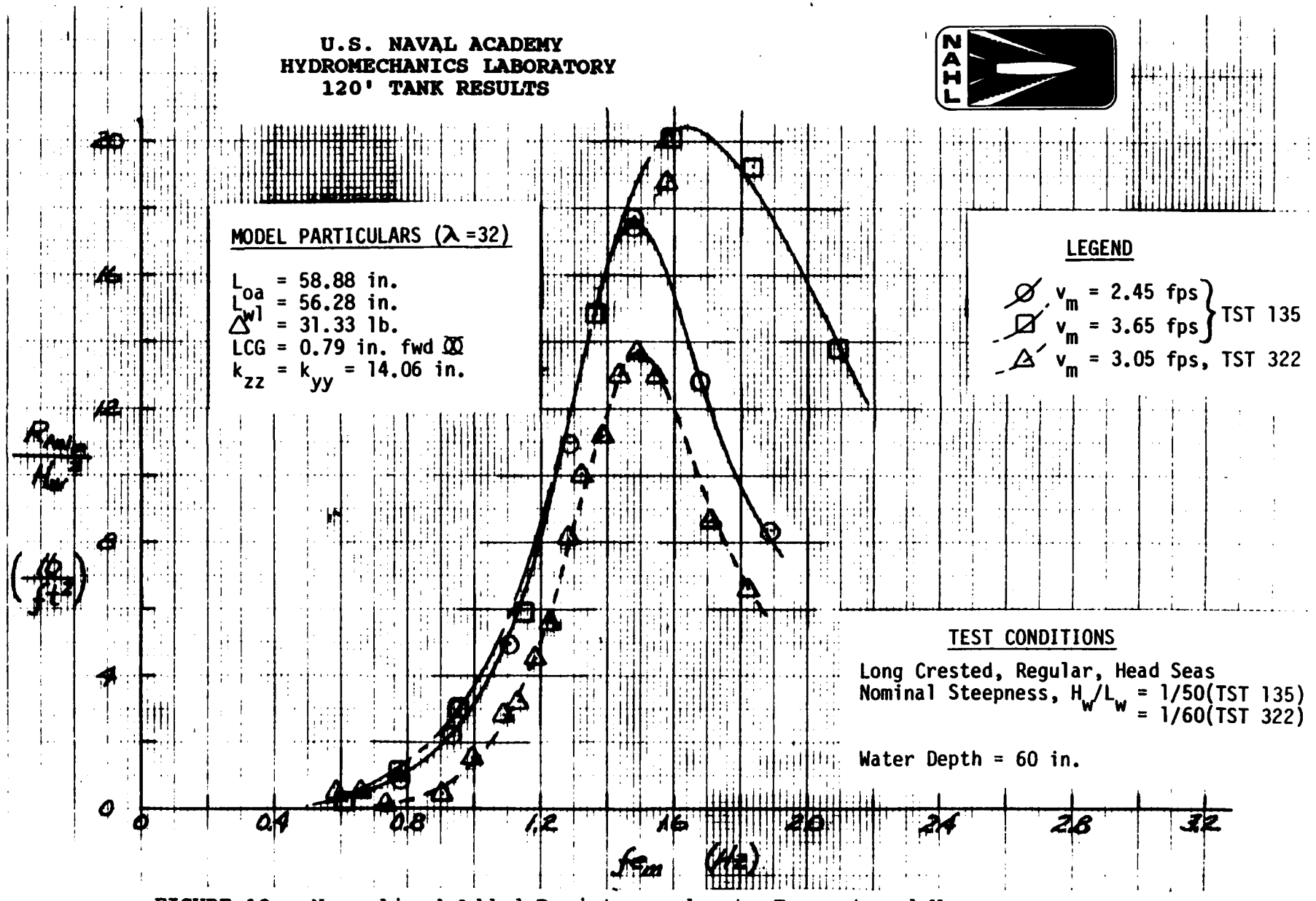



FIGURE 12: Normalized Added Resistance due to Encountered Waves versus Model Encounter Frequency for 157' WLM at Three Model Speeds

$$\left[\frac{R_{AW}(lbs)}{Hw^2(ft^2)}\right]_{SHIP} = \left[\frac{R_{AW}(lbs)}{Hw^2(ft^2)}\right]_{MODEL} \times \lambda \times \frac{\rho\ SHIP}{\rho\ MODEL}$$

Encounter frequency and speed scale as given earlier. $R_{AW}$ is assumed to scale as $\lambda^3$ since it is treated as is residuary resistance. The cumulative tabular and graphical summaries of measured model data for tests is regular, long crested, head waves are contained in Appendix B. These data are unfaired and come directly from the acquisition and analysis software with no interpretation by the test engineer. They are provided to permit the reader to interpret the data as he or she sees fit.

Irregular, long crested, head sea testing was also performed on the WAGL model in the 120 ft. towing tank. An irregular wave system satisfying the model scale, stationary spectrum shown in Figure 13 was developed and used. This spectrum represents Sea State 3 for the 1:32 scale of the subject model. Discrete model speeds of 2.45 fps and 3.65 fps were run. Table 4 summarizes the statistical results obtained.

DATA BASE:

The cumulative tabular and graphical summaries of measured data at model scale are contained in Appendices A and B. These data are unfaired and come directly from the acquisition and analysis software with no interpretation by the test engineer. They are provided to permit the reader to interpret the data as he or she sees fit.

ACKNOWLEDGMENTS:

The author would like to acknowledge Mr. Steve Enzinger and midshipmen naval architects of the Class of 1988 for conducting the experimental work described herein.

TABLE 4

USCG 157′ WLM

IRREGULAR, LONG CRESTED, HEAD SEA MODEL DATA

120′ TANK $\lambda = 32$ $k_{zz} = 0.25$ Lpp

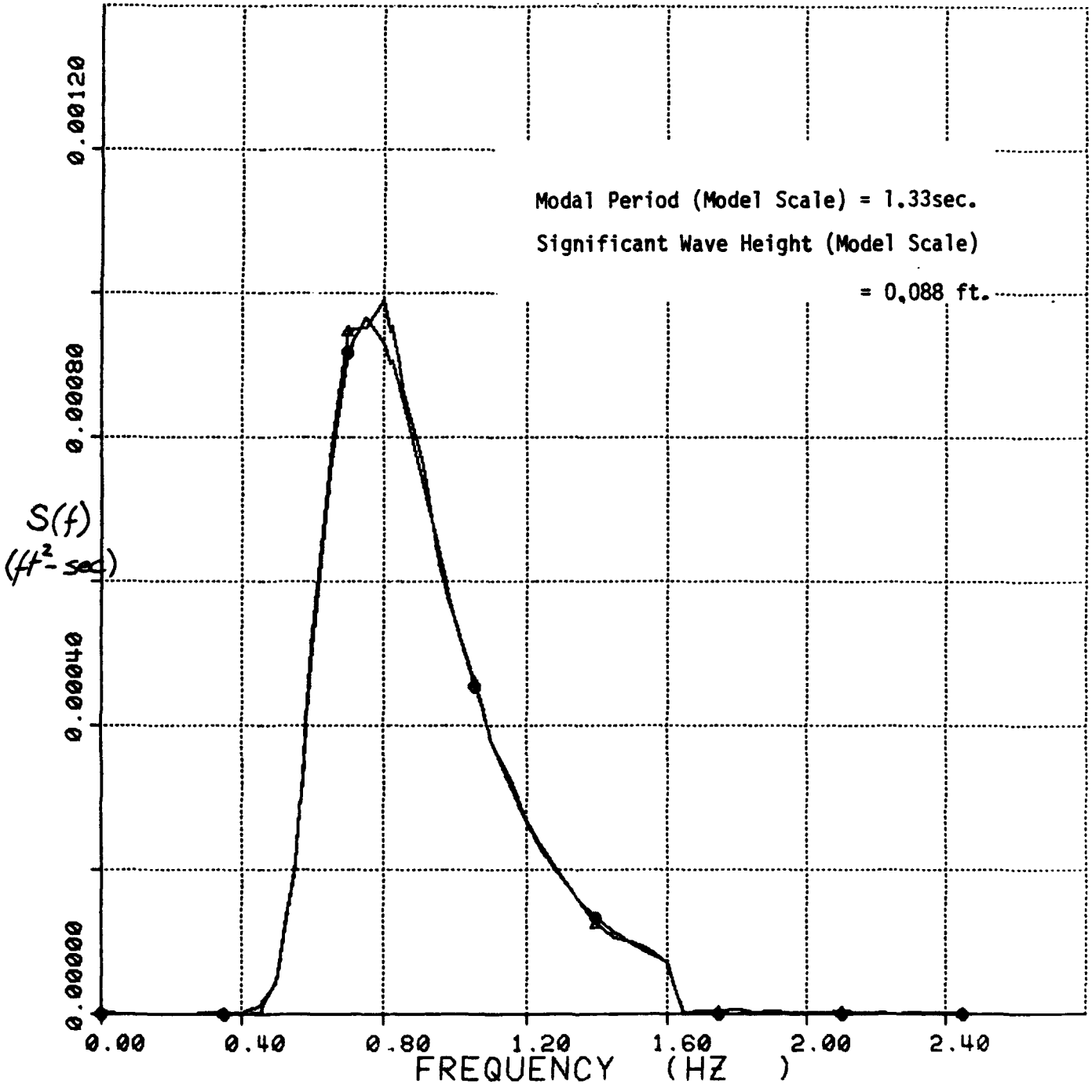
| TANK STATIONARY SPECTRUM (FIGURE 13): | | |
|---|---|---|
| | $T_{modal}$ = 1.33 sec. | 7.53 sec. |
| | $\overline{H_{1/3}}$ = 0.088 ft. (model) | 2.83 ft. (ship) |
| Average Model Velocity, $\overline{v_m}$ | 2.45 fps | 3.65 fps |
| Average Model Resistance in Waves, $R_{Tmw}$ | 0.190 lb. | 0.546 lb. |
| Model Resistance in Calm Water, $R_{Tmsw}$ | 0.146 lb. | 0.495 lb. |
| Average Model Added Resistance due to Waves, $R_{Awm}$ | 0.044 lb. | 0.051 lb. |
| Average of the 1/3 Highest Pitch Double Amplitude, $2\theta_{1/3} = 4\sigma_\theta$ | 2.96° | 3.26° |
| Average of the 1/3 Highest $2z_{1/3} = 4\sigma_z$ | 0.056 ft. | 0.070 ft. |
| Significant Encountered Wave Height, $H_{1/3e} = 4\sigma_w$ | 0.092 ft. | 0.095 ft. |

TEST:140 RUN NO: 0 DATE:26-OCT-88 TIME:10:08:50

● = WAG.DES (FEET**2/HZ)-ALL T140/S 0

▲ = WAG.ACH (FEET**2/HZ**)-ALL T140/S 0

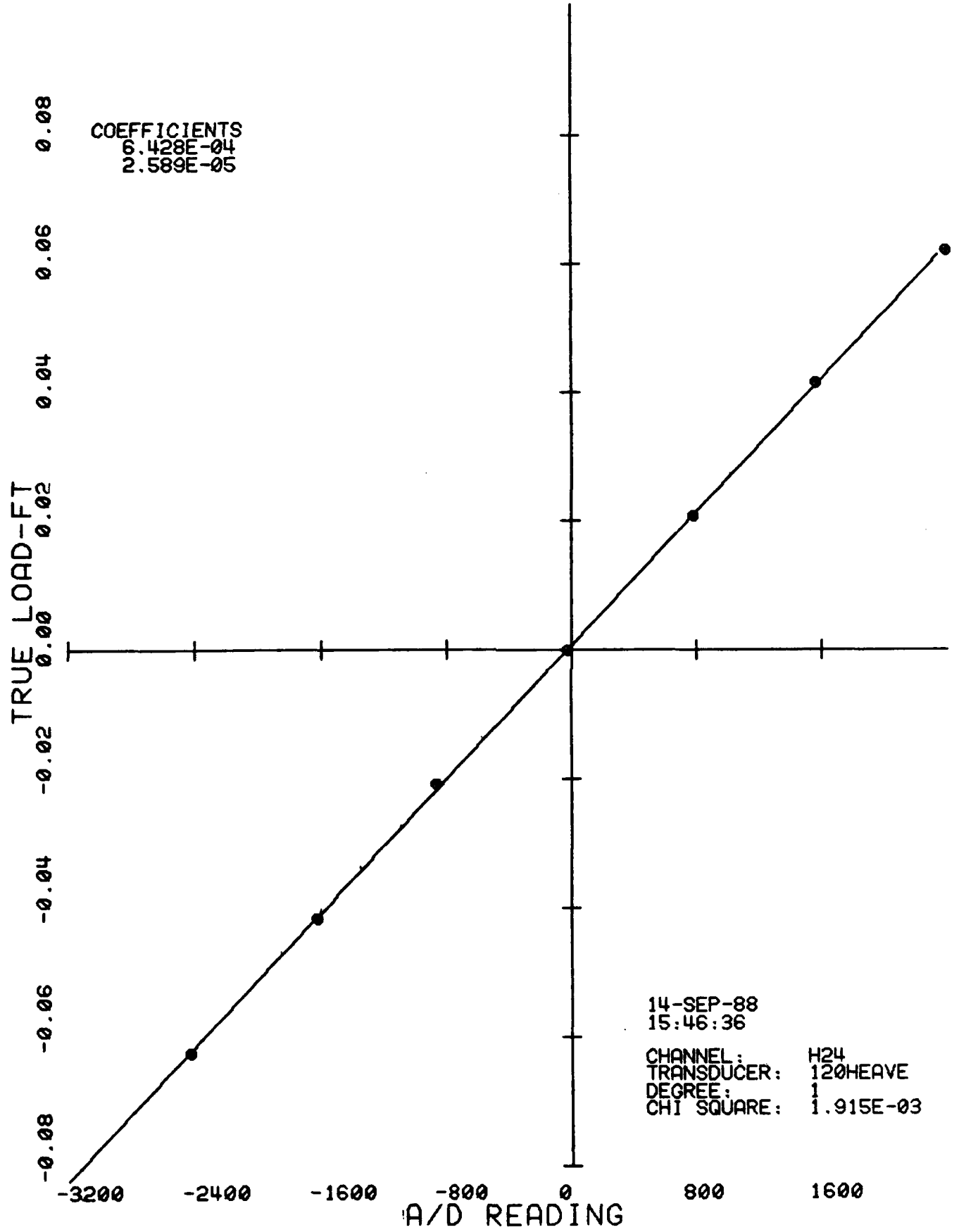
**FIGURE 13: Tank Wave Spectrum of Irregular, Long Crested Wave System for 157' WLM Testing**

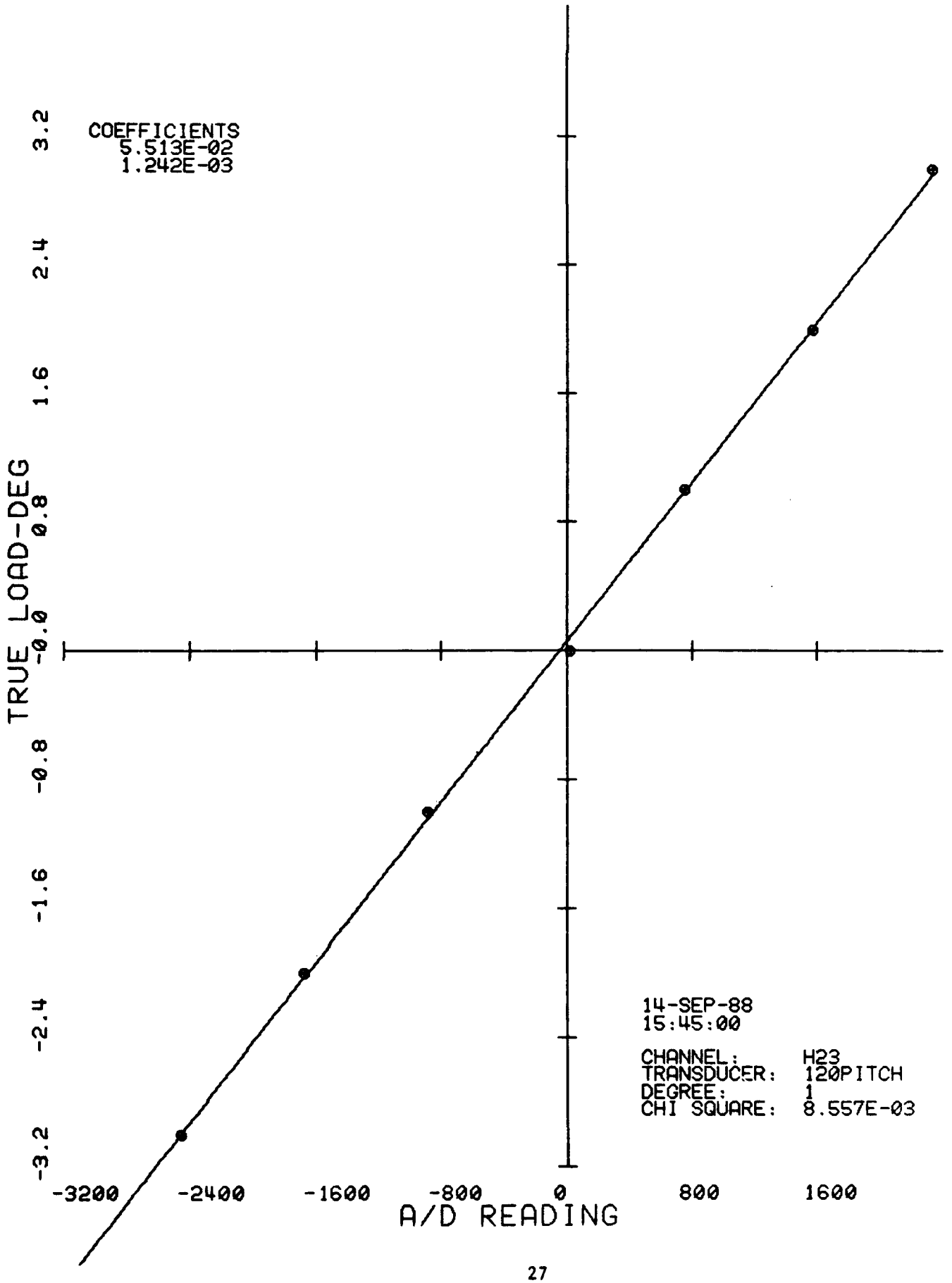


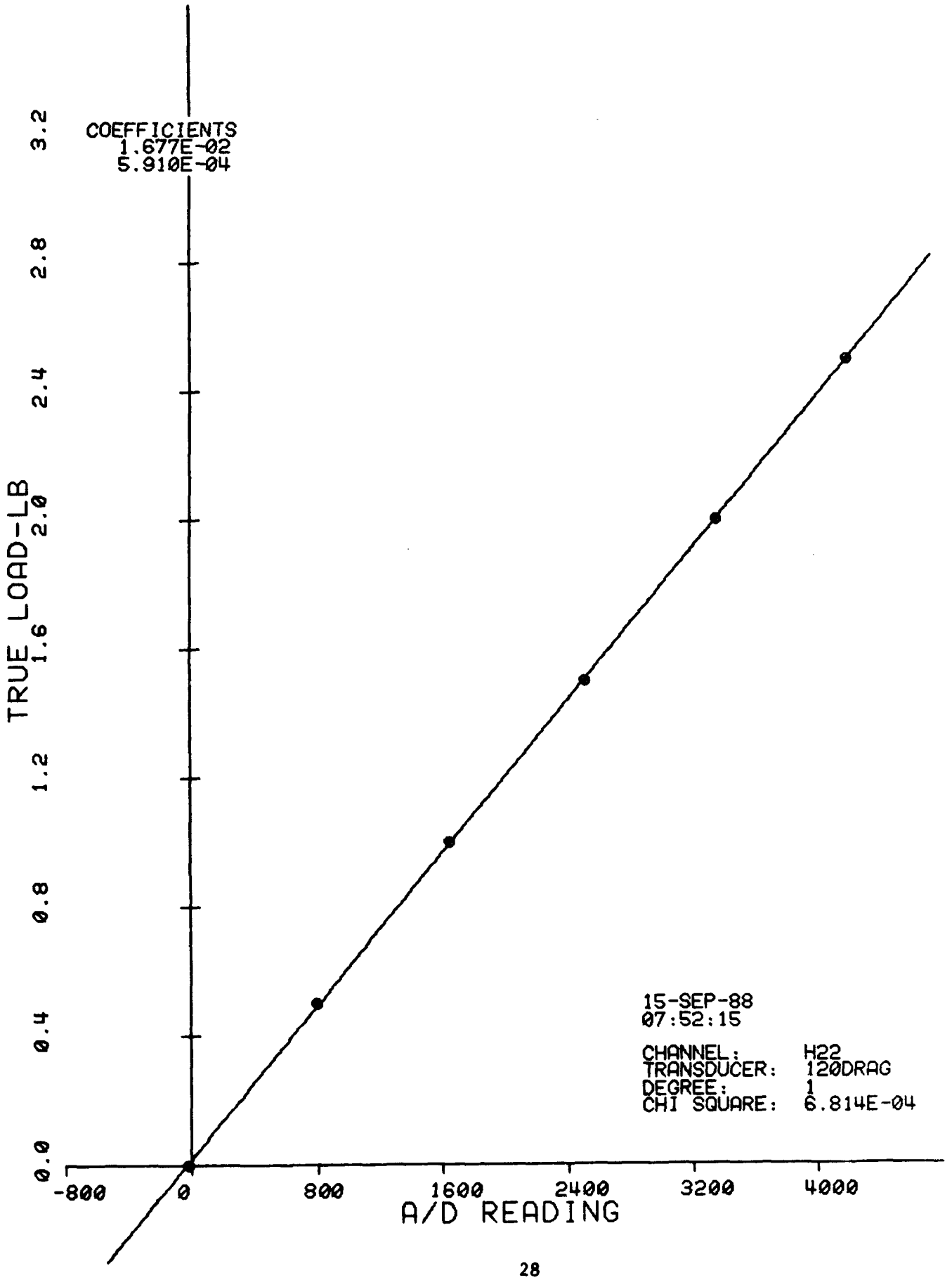
# APPENDIX A

## CALM WATER TEST DATA

- Calibration Curves
- TST 323 - Deep Water @ 63.5°F
- TST 443 - Deep Water @ 68.0°F
- TST 451 - Shallow Water ($h_s$ = 12 feet) @ 67.5°F
- TST 452 - Shallow Water ($h_s$ = 15 feet) @ 67.5°F


COEFFICIENTS
6.428E-04
2.589E-05
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
TRUE LOAD-FT
-3200
-2400
-1600
-800
0
800
1600
A/D READING
14-SEP-88
15:46:36
CHANNEL: H24
TRANSDUCER: 120HEAVE
DEGREE: 1
CHI SQUARE: 1.915E-03


COEFFICIENTS
5.513E-02
1.242E-03
TRUE LOAD-DEG
3.2
2.4
1.6
0.8
-0.0
-0.8
-1.6
-2.4
-3.2
-3200
-2400
-1600
-800
0
800
1600
A/D READING
14-SEP-88
15:45:00
CHANNEL: H23
TRANSDUCER: 120PITCH
DEGREE: 1
CHI SQUARE: 8.557E-03


COEFFICIENTS
1.677E-02
5.910E-04
TRUE LOAD-LB
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
-800
0
800
1600
2400
3200
4000
A/D READING
15-SEP-88
07:52:15
CHANNEL: H22
TRANSDUCER: 120DRAG
DEGREE: 1
CHI SQUARE: 6.814E-04

USNA HYDROMECHANICS LABORATORY

MODEL DATA TABULATION

TEST NO.: 323 TEST TYPE: EHP, STILL WATER, 12Ø, PC START DATE: 2Ø-DEC-89 LOG DATE: 22-MAY-9Ø, Ø9:31:25

MODEL NAME: WAGL LWL: 4.69Ø FT DISPLACEMENT: 31.3 LBS

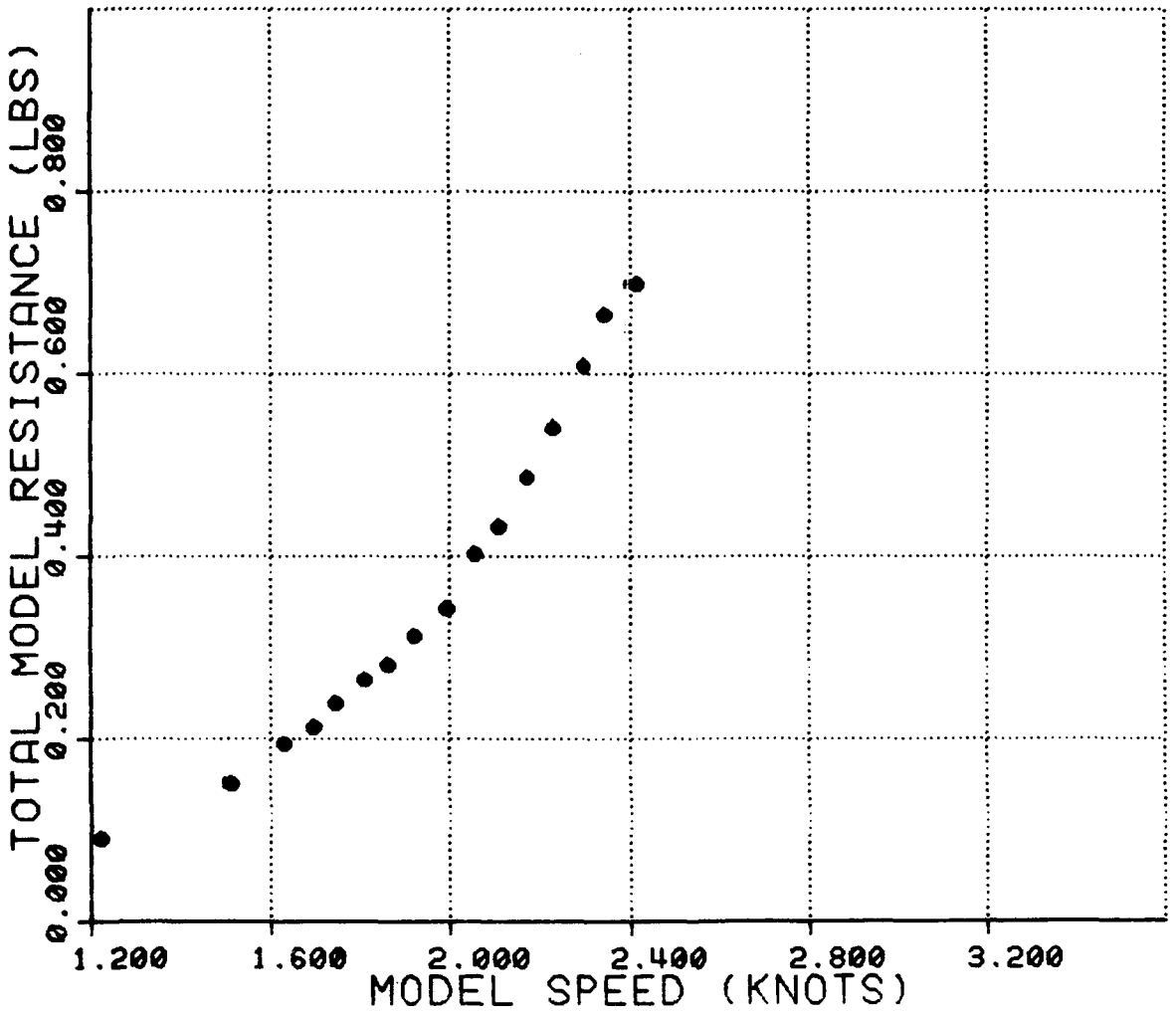
WET SURFACE: 4.424 SQ FT LCG: Ø.Ø63 FT STIMULATOR: STUDS

| RUN # | VM (KTS) | RTM (LBS) | FP RISE (FEET) | AP RISE (FEET) | TRIM (DEG) | FROUDE # | CTM - | RENLD # | CFM - | TEMP (F) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.81Ø | Ø.264 | -Ø.Ø14 | -Ø.ØØ2 | -Ø.14 | Ø.249 | Ø.66Ø7E-Ø2 | Ø.1246E+Ø7 | Ø.4471E-Ø2 | 63.5 |
| 2 | 1.22Ø | Ø.ØØØ | -Ø.ØØ7 | -Ø.ØØ1 | -Ø.Ø7 | Ø.168 | Ø.4946E-Ø2 | Ø.84Ø2E+Ø6 | Ø.487ØE-Ø2 | 63.5 |
| 3 | 2.413 | Ø.697 | -Ø.Ø2Ø | -Ø.ØØ9 | -Ø.13 | Ø.332 | Ø.98Ø9E-Ø2 | Ø.1661E+Ø7 | Ø.4211E-Ø2 | 63.5 |
| 4 | 1.513 | Ø.149 | -Ø.Ø11 | -Ø.ØØ2 | -Ø.11 | Ø.2Ø8 | Ø.5342E-Ø2 | Ø.1Ø42E+Ø7 | Ø.4646E-Ø2 | 63.5 |
| 5 | 1.991 | Ø.343 | -Ø.Ø17 | -Ø.ØØ3 | -Ø.17 | Ø.274 | Ø.7ØØ7E-Ø2 | Ø.1371E+Ø7 | Ø.4382E-Ø2 | 63.5 |
| 6 | 1.926 | Ø.313 | -Ø.Ø18 | -Ø.ØØ3 | -Ø.19 | Ø.265 | Ø.69Ø3E-Ø2 | Ø.1326E+Ø7 | Ø.4413E-Ø2 | 63.5 |
| 7 | 1.626 | Ø.194 | -Ø.Ø12 | -Ø.ØØ3 | -Ø.11 | Ø.224 | Ø.6Ø12E-Ø2 | Ø.112ØE+Ø7 | Ø.4574E-Ø2 | 63.5 |
| 8 | 2.224 | Ø.54Ø | -Ø.Ø22 | -Ø.Ø1Ø | -Ø.15 | Ø.3Ø6 | Ø.8947E-Ø2 | Ø.1531E+Ø7 | Ø.4282E-Ø2 | 63.5 |
| 9 | 2.1Ø1 | Ø.431 | -Ø.Ø21 | -Ø.ØØ6 | -Ø.19 | Ø.289 | Ø.8ØØ1E-Ø2 | Ø.1447E+Ø7 | Ø.4333E-Ø2 | 63.5 |
| 1Ø | 2.Ø48 | Ø.4Ø3 | -Ø.Ø16 | -Ø.ØØ3 | -Ø.16 | Ø.281 | Ø.786ØE-Ø2 | Ø.141ØE+Ø7 | Ø.4356E-Ø2 | 63.5 |
| 11 | 1.697 | Ø.212 | -Ø.Ø12 | -Ø.ØØ2 | -Ø.12 | Ø.233 | Ø.6Ø25E-Ø2 | Ø.1168E+Ø7 | Ø.4533E-Ø2 | 63.5 |
| 12 | 2.291 | Ø.6Ø9 | -Ø.Ø22 | -Ø.Ø11 | -Ø.13 | Ø.315 | Ø.95Ø3E-Ø2 | Ø.1577E+Ø7 | Ø.4256E-Ø2 | 63.5 |
| 13 | 2.164 | Ø.486 | -Ø.Ø18 | -Ø.ØØ5 | -Ø.16 | Ø.297 | Ø.8494E-Ø2 | Ø.149ØE+Ø7 | Ø.43Ø6E-Ø2 | 63.5 |
| 14 | 1.864 | Ø.28Ø | -Ø.Ø17 | -Ø.ØØ3 | -Ø.18 | Ø.256 | Ø.6596E-Ø2 | Ø.1284E+Ø7 | Ø.4443E-Ø2 | 63.5 |
| 15 | 2.341 | Ø.663 | -Ø.Ø23 | -Ø.Ø1Ø | -Ø.16 | Ø.322 | Ø.991ØE-Ø2 | Ø.1612E+Ø7 | Ø.4237E-Ø2 | 63.5 |
| 16 | 1.743 | Ø.239 | -Ø.Ø15 | -Ø.ØØ2 | -Ø.15 | Ø.24Ø | Ø.6433E-Ø2 | Ø.12ØØE+Ø7 | Ø.45Ø7E-Ø2 | 63.5 |

USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

| | | | |
|---|---|---|---|
| TEST NO.: | 323 | START DATE: | 20-DEC-89 13:37:03 |
| TEST TYPE: | EHP,SW ,120 PC | LOG DATE: | 22-MAY-90 09:31:25 |
| MODEL NAME: | WAGL | LWL: | 4.69 FT |
| DISPLACEMENT: | 31.3 LBS | LCG: | 0.063 FT |
| WET SURFACE: | 4.4 SQ FT | STIM: | STUDS |
| WATER TEMP: | 63.5 F | | |

TOTAL MODEL RESISTANCE(RTM)

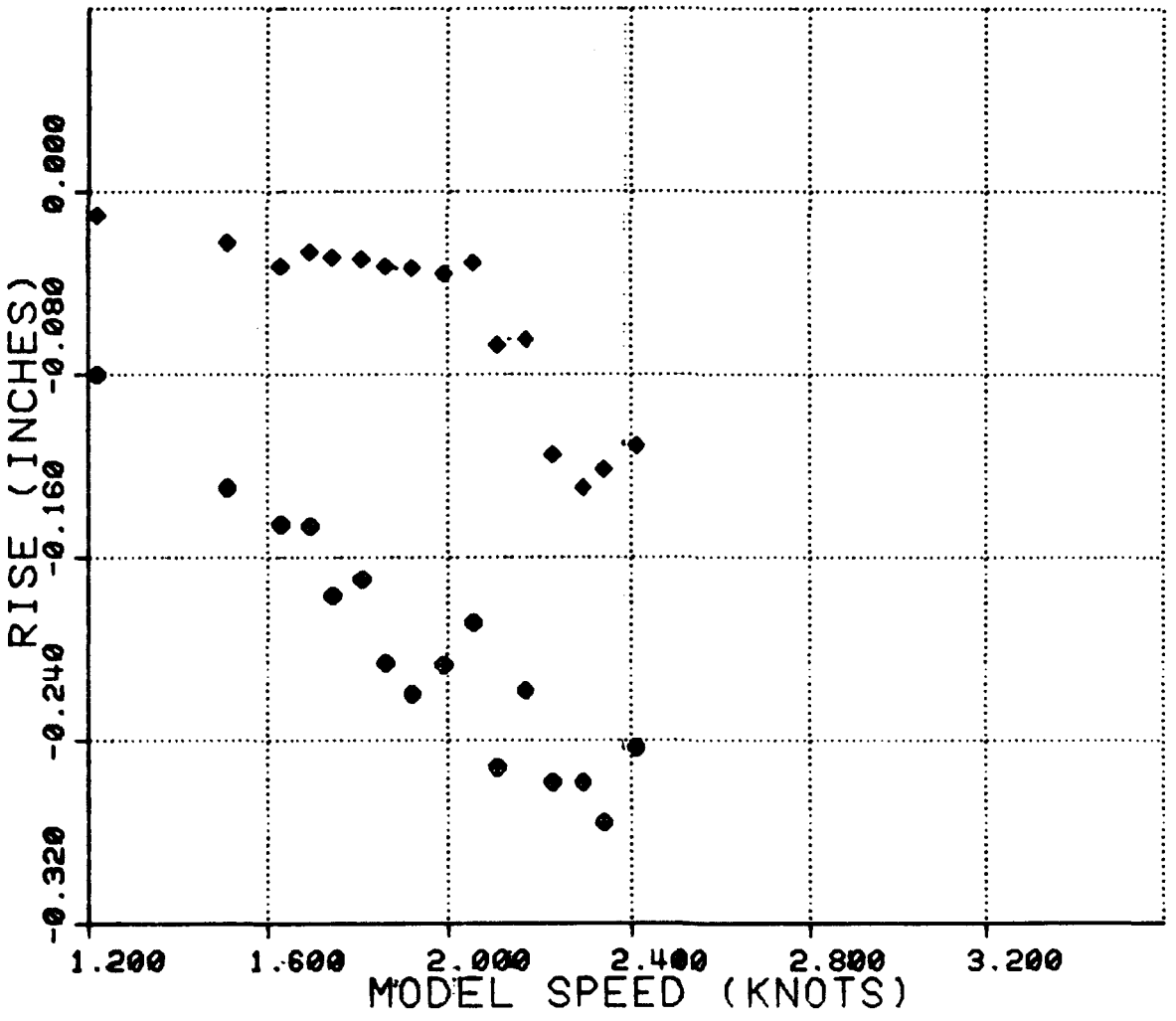


USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

| | | | |
|---|---|---|---|
| TEST NO.: | 323 | START DATE: | 20-DEC-89 13:37:03 |
| TEST TYPE: | EHP,SW ,120 PC | LOG DATE: | 22-MAY-90 09:31:25 |

| | | | |
|---|---|---|---|
| MODEL NAME: | WAGL | LWL: | 4.69 FT |
| DISPLACEMENT: | 31.3 LBS | LCG: | 0.063 FT |
| WET SURFACE: | 4.4 SQ FT | STIM: | STUDS |
| WATER TEMP: | 63.5 F | | |

LEGEND: ●-FP RISE ◆-AP RISE

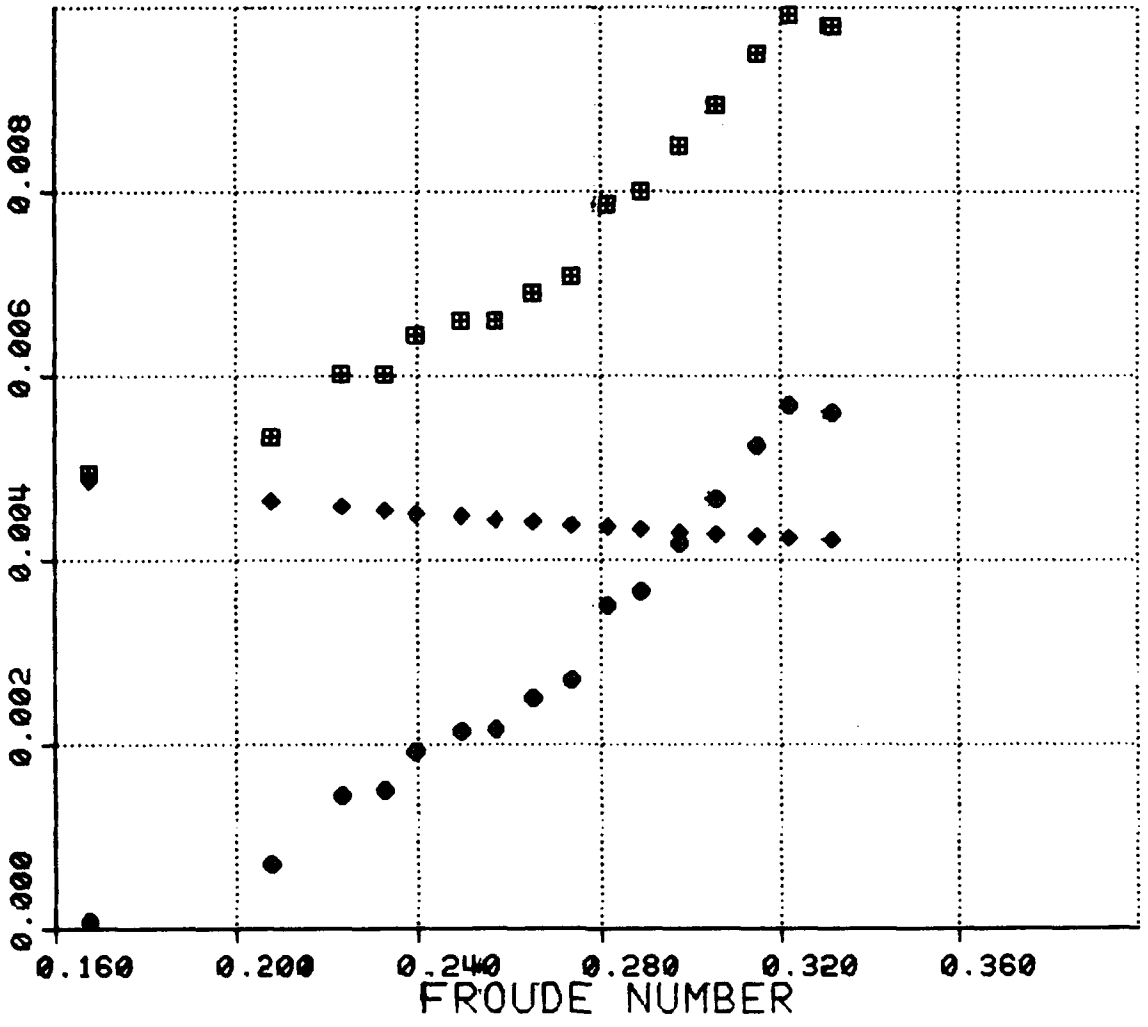


USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

TEST NO.: 323 START DATE: 20-DEC-89 13:37:03
TEST TYPE: EHP,SW ,120 PC LOG DATE: 22-MAY-90 09:31:25

MODEL NAME: WAGL LWL: 4.69 FT
DISPLACEMENT: 31.3 LBS LCG: 0.063 FT
WET SURFACE: 4.4 SQ FT STIM: STUDS
WATER TEMP: 63.5 F

LEGEND: ⊞=CTM ◆=CFM ⊕=CRM



USNA HYDROMECHANICS LABORATORY

MODEL DATA TABULATION

TEST NO.: 443 TEST TYPE: EHP, STILL WATER, 12Ø, PC START DATE: 14-SEP-88 LOG DATE: 15-SEP-88, 15:29:Ø6

MODEL NAME: WAGL 157 LWL: 4.69Ø FT DISPLACEMENT: 31.3 LBS

WET SURFACE: 4.424 SQ FT LCG: Ø.Ø63 FT STIMULATOR: STUDS

| RUN # | VM (KTS) | RTM (LBS) | FP RISE (FEET) | AP RISE (FEET) | TRIM (DEG) | FROUDE # | CTM - | RENLD # | CFM - | TEMP (F) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.496 | Ø.154 | ~~-Ø.1Ø4~~ | ~~-Ø.134~~ | -Ø.37 | Ø.2Ø6 | Ø.5646E-Ø2 | Ø.1Ø96E+Ø7 | Ø.4596E-Ø2 | 68.Ø |
| 2 | 1.8Ø2 | Ø.267 | -Ø.Ø17 | -Ø.ØØ6 | -Ø.14 | Ø.248 | Ø.6742E-Ø2 | Ø.132ØE+Ø7 | Ø.4417E-Ø2 | 68.Ø |
| 3 | 1.917 | Ø.3Ø7 | -Ø.Ø23 | -Ø.ØØ9 | -Ø.17 | Ø.263 | Ø.6838E-Ø2 | Ø.14Ø4E+Ø7 | Ø.436ØE-Ø2 | 68.Ø |
| 4 | 1.681 | Ø.2Ø7 | -Ø.Ø21 | -Ø.Ø1Ø | -Ø.13 | Ø.231 | Ø.5995E-Ø2 | Ø.1232E+Ø7 | Ø.4482E-Ø2 | 68.Ø |
| 5 | 2.Ø4Ø | Ø.379 | -Ø.Ø13 | Ø.ØØ2 | -Ø.19 | Ø.28Ø | Ø.7471E-Ø2 | Ø.1494E+Ø7 | Ø.43Ø4E-Ø2 | 68.Ø |
| 6 | 1.56Ø | Ø.166 | -Ø.ØØ9 | Ø.ØØØ | -Ø.11 | Ø.214 | Ø.5583E-Ø2 | Ø.1143E+Ø7 | Ø.4554E-Ø2 | 68.Ø |
| 7 | 2.156 | Ø.48Ø | -Ø.Ø2Ø | -Ø.ØØ7 | -Ø.16 | Ø.296 | Ø.8457E-Ø2 | Ø.1579E+Ø7 | Ø.4255E-Ø2 | 68.Ø |
| 8 | 2.139 | Ø.465 | -Ø.Ø22 | -Ø.ØØ9 | -Ø.16 | Ø.294 | Ø.8326E-Ø2 | Ø.1567E+Ø7 | Ø.4261E-Ø2 | 68.Ø |
| 9 | 1.442 | Ø.132 | -Ø.Ø16 | -Ø.ØØ9 | -Ø.Ø8 | Ø.198 | Ø.52ØØE-Ø2 | Ø.1Ø57E+Ø7 | Ø.4632E-Ø2 | 68.Ø |
| 1Ø | 2.277 | Ø.618 | -Ø.Ø14 | -Ø.ØØ3 | -Ø.14 | Ø.313 | Ø.9762E-Ø2 | Ø.1668E+Ø7 | Ø.42Ø7E-Ø2 | 68.Ø |
| 11 | 1.322 | Ø.127 | Ø.ØØ3 | Ø.ØØØ | -Ø.Ø6 | Ø.182 | Ø.5973E-Ø2 | Ø.9689E+Ø6 | Ø.472ØE-Ø2 | 68.Ø |
| 12 | 2.4ØØ | Ø.726 | -Ø.Ø14 | -Ø.ØØ4 | -Ø.12 | Ø.33Ø | Ø.1Ø32E-Ø1 | Ø.1758E+Ø7 | Ø.4162E-Ø2 | 68.Ø |
| 13 | 1.21Ø | Ø.Ø97 | -Ø.ØØ2 | Ø.ØØ2 | -Ø.Ø5 | Ø.166 | Ø.5427E-Ø2 | Ø.8867E+Ø6 | Ø.4812E-Ø2 | 68.Ø |
| 14 | 2.514 | Ø.851 | -Ø.Ø16 | -Ø.ØØ7 | -Ø.12 | Ø.345 | Ø.11Ø4E-Ø1 | Ø.1842E+Ø7 | Ø.4123E-Ø2 | 68.Ø |
| 15 | 1.443 | Ø.172 | -Ø.ØØ9 | -Ø.ØØ2 | -Ø.Ø9 | Ø.198 | Ø.6774E-Ø2 | Ø.1Ø57E+Ø7 | Ø.4631E-Ø2 | 68.Ø |
| 16 | 2.616 | Ø.938 | -Ø.Ø31 | -Ø.Ø17 | -Ø.17 | Ø.36Ø | Ø.1123E-Ø1 | Ø.1917E+Ø7 | Ø.4Ø89E-Ø2 | 68.Ø |
| 17 | 1.444 | Ø.17Ø | -Ø.Ø14 | -Ø.ØØ7 | -Ø.Ø9 | Ø.198 | Ø.67Ø4E-Ø2 | Ø.1Ø58E+Ø7 | Ø.4631E-Ø2 | 68.Ø |
| 18 | 2.688 | Ø.988 | -Ø.Ø25 | -Ø.Ø14 | -Ø.14 | Ø.369 | Ø.112ØE-Ø1 | Ø.1969E+Ø7 | Ø.4Ø67E-Ø2 | 68.Ø |
| 19 | 2.153 | Ø.496 | -Ø.ØØ7 | Ø.ØØ7 | -Ø.17 | Ø.296 | Ø.8758E-Ø2 | Ø.1578E+Ø7 | Ø.4256E-Ø2 | 68.Ø |
| 2Ø | 2.154 | Ø.494 | -Ø.ØØ9 | Ø.ØØ3 | -Ø.15 | Ø.296 | Ø.8724E-Ø2 | Ø.1578E+Ø7 | Ø.4255E-Ø2 | 68.Ø |

TEST NO.: 443 TEST TYPE: EHP, STILL WATER, 12Ø, PC START DATE: 14-SEP-88 LOG DATE: 15-SEP-88, 15:29:Ø6

MODEL NAME: WAGL 157 LWL: 4.69Ø FT DISPLACEMENT: 31.3 LBS

WET SURFACE: 4.424 SQ FT LCG: Ø.Ø63 FT STIMULATOR: STUDS

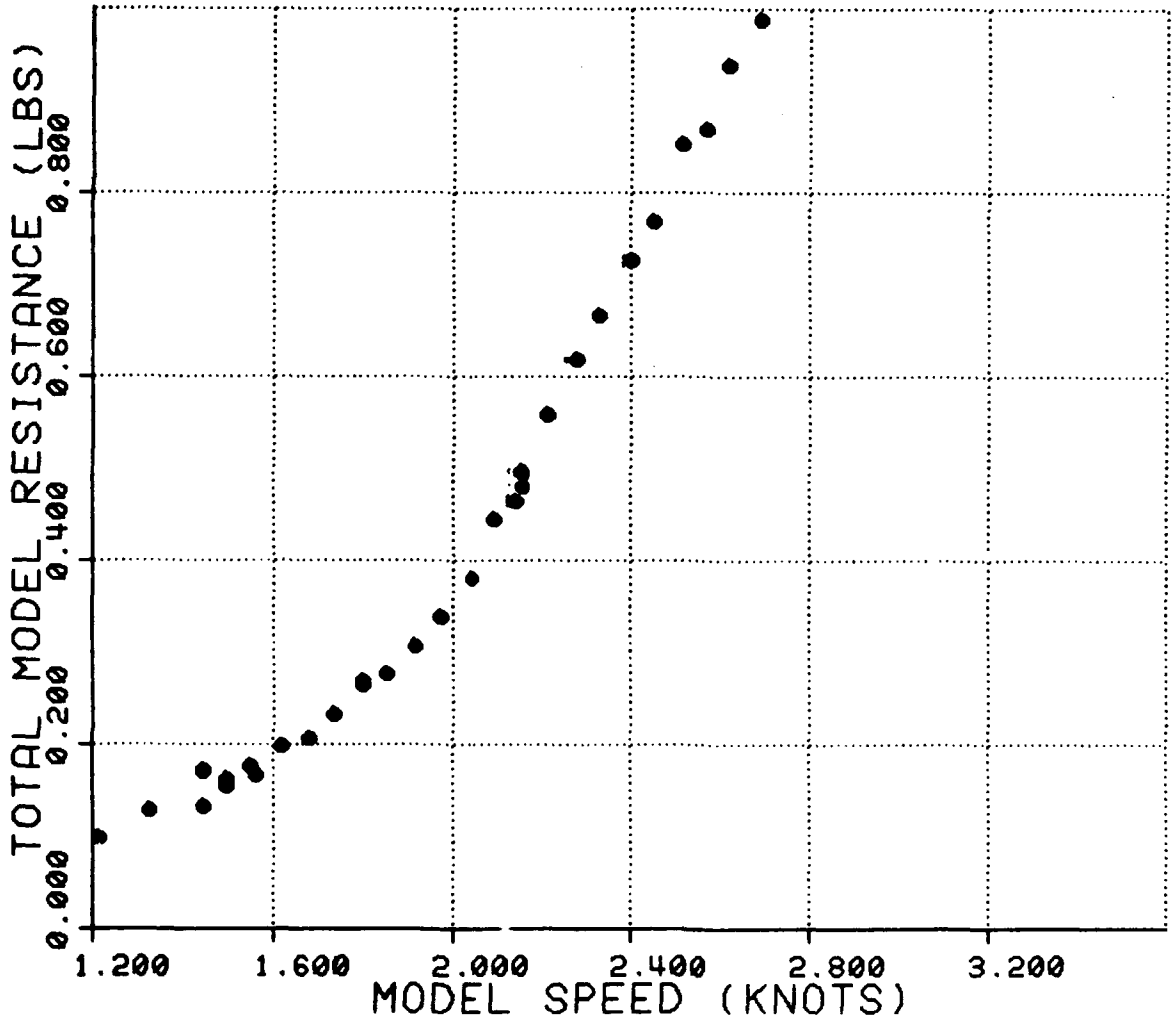
| RUN # | VM (KTS) | RTM (LBS) | FP RISE (FEET) | AP RISE (FEET) | TRIM (DEG) | FROUDE # | CTM - | RENLD # | CFM - | TEMP (F) |
|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 1.854 | Ø.276 | -Ø.Ø17 | -Ø.ØØ4 | -Ø.16 | Ø.255 | Ø.6585E-Ø2 | Ø.1358E+Ø7 | Ø.4391E-Ø2 | 68.Ø |
| 22 | 1.971 | Ø.339 | -Ø.Ø19 | -Ø.ØØ6 | -Ø.17 | Ø.271 | Ø.7142E-Ø2 | Ø.1444E+Ø7 | Ø.4335E-Ø2 | 68.Ø |
| 23 | 1.733 | Ø.233 | -Ø.Ø18 | -Ø.ØØ8 | -Ø.12 | Ø.238 | Ø.6355E-Ø2 | Ø.1269E+Ø7 | Ø.4454E-Ø2 | 68.Ø |
| 24 | 2.Ø94 | Ø.444 | -Ø.Ø14 | Ø.ØØ1 | -Ø.18 | Ø.288 | Ø.8293E-Ø2 | Ø.1534E+Ø7 | Ø.4281E-Ø2 | 68.Ø |
| 25 | 1.616 | Ø.198 | Ø.ØØ1 | Ø.Ø1Ø | -Ø.11 | Ø.222 | Ø.6198E-Ø2 | Ø.1184E+Ø7 | Ø.452ØE-Ø2 | 68.Ø |
| 26 | 2.211 | Ø.557 | -Ø.Ø12 | Ø.ØØ1 | -Ø.15 | Ø.3Ø4 | Ø.9335E-Ø2 | Ø.162ØE+Ø7 | Ø.4232E-Ø2 | 68.Ø |
| 27 | 1.8Ø2 | Ø.263 | -Ø.ØØ9 | Ø.ØØ3 | -Ø.14 | Ø.248 | Ø.6644E-Ø2 | Ø.132ØE+Ø7 | Ø.4417E-Ø2 | 68.Ø |
| 28 | 2.328 | Ø.666 | -Ø.Ø18 | -Ø.ØØ7 | -Ø.14 | Ø.32Ø | Ø.1ØØ7E-Ø1 | Ø.17Ø6E+Ø7 | Ø.4188E-Ø2 | 68.Ø |
| 29 | 1.549 | Ø.176 | -Ø.Ø1Ø | -Ø.ØØ1 | -Ø.1Ø | Ø.213 | Ø.6Ø21E-Ø2 | Ø.1135E+Ø7 | Ø.4562E-Ø2 | 68.Ø |
| 3Ø | 2.453 | Ø.768 | -Ø.Ø16 | -Ø.ØØ5 | -Ø.12 | Ø.337 | Ø.1Ø46E-Ø1 | Ø.1797E+Ø7 | Ø.4143E-Ø2 | 68.Ø |
| 31 | 1.497 | Ø.163 | Ø.ØØ3 | Ø.Ø1Ø | -Ø.Ø9 | Ø.2Ø6 | Ø.5945E-Ø2 | Ø.1Ø97E+Ø7 | Ø.4595E-Ø2 | 68.Ø |
| 32 | 2.569 | Ø.868 | -Ø.Ø17 | -Ø.ØØ4 | -Ø.15 | Ø.353 | Ø.1Ø78E-Ø1 | Ø.1882E+Ø7 | Ø.41Ø4E-Ø2 | 68.Ø |

USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

| | |
|---|---|
| TEST NO. 443 | START DATE: 14-SEP-88 15:29:51 |
| TEST TYPE: EHP,SW ,120 PC | LOG DATE: 15-SEP-88 15:29:06 |

| | |
|---|---|
| MODEL NAME: WAGL 157 | LWL: 4.69 FT |
| DISPLACEMENT: 31.3 LBS | LCG: 0.063 FT |
| WET SURFACE: 4.4 SQ FT | STIM: STUDS |
| WATER TEMP: 68.0 F | |

TOTAL MODEL RESISTANCE(RTM)

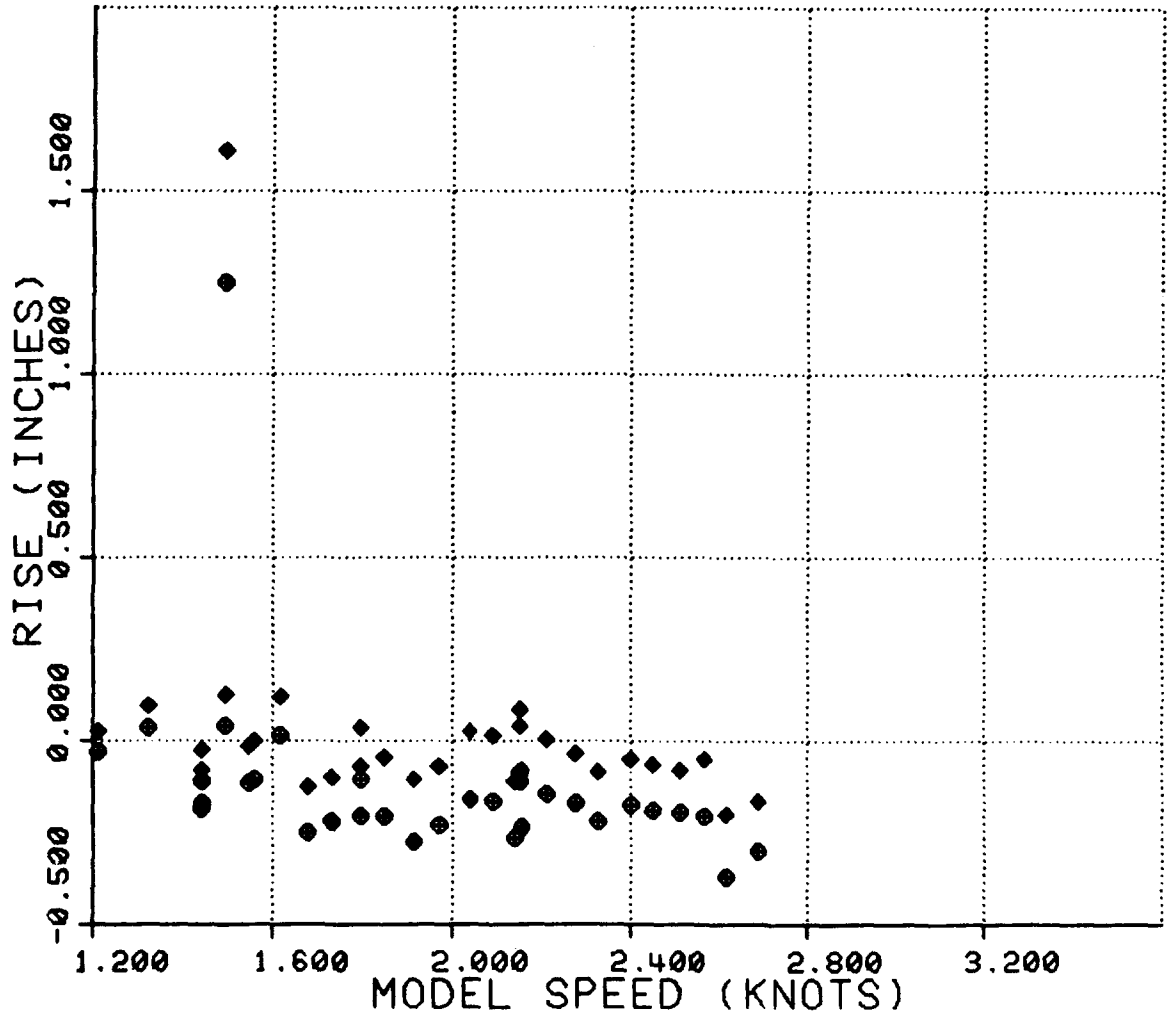


USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

TEST NO.: 443 START DATE: 14-SEP-88 15:20:51
TEST TYPE: EHP,SW ,120 PC LOG DATE: 15-SEP-88 15:20:06

MODEL NAME: WAGL 157 LWL: 4.69 FT
DISPLACEMENT: 31.3 LBS LCG: 0.063 FT
WET SURFACE: 4.4 SQ FT STIM: STUDS
WATER TEMP: 68.0 F

LEGEND: ⊕=FP RISE ◆=AP RISE

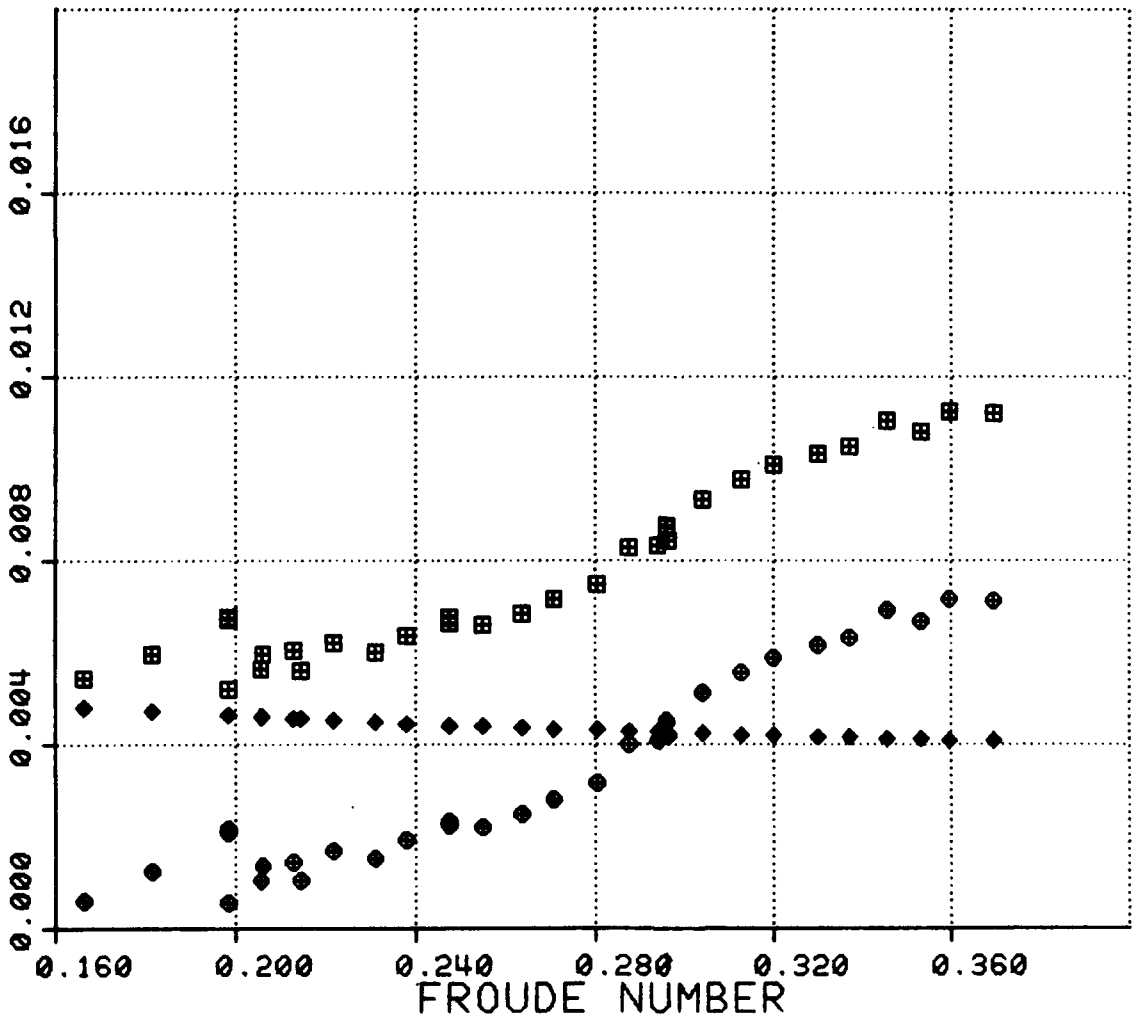


USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

TEST NO.: 443 START DATE: 14-SEP-88 15:29:51
TEST TYPE: EHP,SW ,120 PC LOG DATE: 15-SEP-88 15:29:06

MODEL NAME: WAGL 157 LWL: 4.69 FT
DISPLACEMENT: 31.3 LBS LCG: 0.063 FT
WET SURFACE: 4.4 SQ FT STIM: STUDS
WATER TEMP: 68.0 F

LEGEND: ⊞ =CTM ◆ =CFM ⊕ =CRM



USNA HYDROMECHANICS LABORATORY

MODEL DATA TABULATION

TEST NO.: 451 TEST TYPE: EHP, STILL WATER, 12Ø, PC START DATE: Ø3-OCT-88 LOG DATE: Ø4-OCT-88, 11:35:19

MODEL NAME: WAGL12FT LWL: 4.69Ø FT DISPLACEMENT: 31.3 LBS

WET SURFACE: 4.424 SQ FT LCG: Ø.Ø63 FT STIMULATOR: STUDS

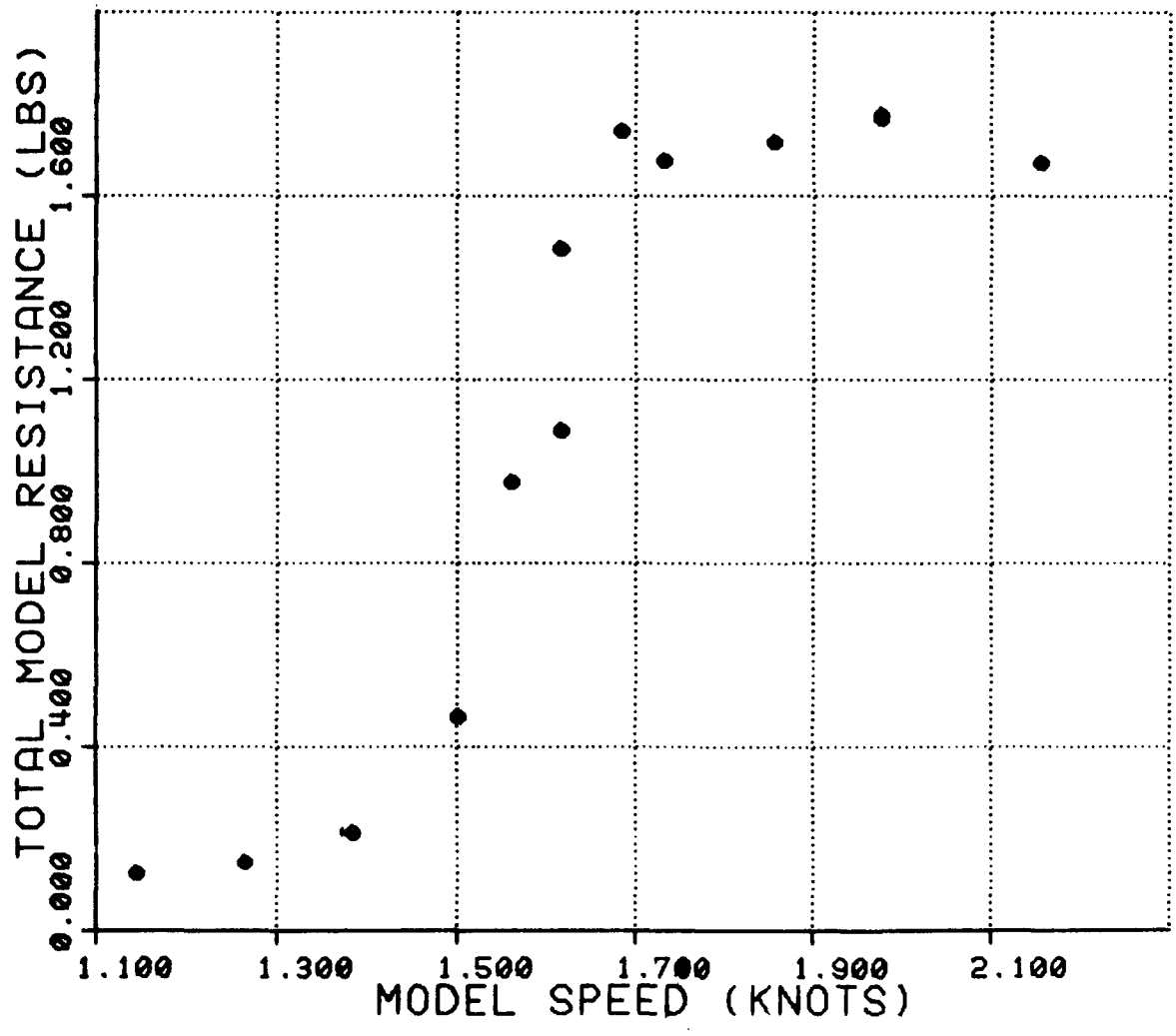
| RUN # | VM (KTS) | RTM (LBS) | FP RISE (FEET) | AP RISE (FEET) | TRIM (DEG) | FROUDE # | CTM - | RENLD # | CFM - | TEMP (F) |
|---|---|---|---|---|---|---|---|---|---|---|
| ~~1~~ | ~~1.616~~ | ~~Ø.Ø86~~ | ~~Ø.ØØØ~~ | ~~-Ø.1Ø2~~ | ~~1.27~~ | ~~Ø.222~~ | ~~Ø.3487E-Ø1~~ | ~~Ø.1176E+Ø7~~ | ~~Ø.4527E-Ø2~~ | ~~67.5~~ |
| 2 | 1.5ØØ | Ø.463 | -Ø.Ø36 | -Ø.Ø51 | Ø.18 | Ø.2Ø6 | Ø.1685E-Ø1 | Ø.1Ø92E+Ø7 | Ø.4599E-Ø2 | 67.5 |
| 3 | 1.733 | 1.674 | Ø.Ø58 | -Ø.155 | 2.6Ø | Ø.238 | Ø.4571E-Ø1 | Ø.1261E+Ø7 | Ø.446ØE-Ø2 | 67.5 |
| 4 | 1.384 | Ø.211 | -Ø.Ø34 | -Ø.Ø22 | -Ø.14 | Ø.19Ø | Ø.9Ø21E-Ø2 | Ø.1ØØ7E+Ø7 | Ø.468ØE-Ø2 | 67.5 |
| 5 | 1.855 | 1.718 | Ø.Ø63 | -Ø.118 | 2.21 | Ø.255 | Ø.4Ø89E-Ø1 | Ø.135ØE+Ø7 | Ø.4396E-Ø2 | 67.5 |
| 6 | 1.264 | Ø.149 | -Ø.Ø28 | -Ø.Ø17 | -Ø.14 | Ø.174 | Ø.767ØE-Ø2 | Ø.9194E+Ø6 | Ø.4774E-Ø2 | 67.5 |
| 7 | 1.975 | 1.77Ø | Ø.Ø84 | -Ø.118 | 2.47 | Ø.272 | Ø.3716E-Ø1 | Ø.1437E+Ø7 | Ø.4339E-Ø2 | 67.5 |
| 8 | 1.144 | Ø.124 | -Ø.Ø2Ø | -Ø.Ø11 | -Ø.1Ø | Ø.157 | Ø.7761E-Ø2 | Ø.8326E+Ø6 | Ø.488ØE-Ø2 | 67.5 |
| 9 | 1.977 | 1.775 | Ø.Ø9Ø | -Ø.126 | 2.64 | Ø.272 | Ø.3722E-Ø1 | Ø.1438E+Ø7 | Ø.4338E-Ø2 | 67.5 |
| 1Ø | 1.617 | 1.483 | Ø.Ø15 | -Ø.Ø76 | 1.11 | Ø.222 | Ø.4648E-Ø1 | Ø.1176E+Ø7 | Ø.4526E-Ø2 | 67.5 |
| 11 | 1.561 | Ø.977 | -Ø.ØØ7 | -Ø.Ø76 | Ø.85 | Ø.215 | Ø.3284E-Ø1 | Ø.1136E+Ø7 | Ø.4561E-Ø2 | 67.5 |
| 12 | 1.684 | 1.742 | Ø.Ø38 | -Ø.126 | 2.Ø1 | Ø.231 | Ø.5Ø34E-Ø1 | Ø.1225E+Ø7 | Ø.4486E-Ø2 | 67.5 |
| 13 | 2.155 | 1.671 | Ø.Ø73 | -Ø.Ø77 | 1.84 | Ø.296 | Ø.295ØE-Ø1 | Ø.1568E+Ø7 | Ø.4261E-Ø2 | 67.5 |

USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

| | |
|---|---|
| TEST NO.: 451 | START DATE: 03-OCT-88 09:17:51 |
| TEST TYPE: EHP,SW ,120 PC | LOG DATE: 04-OCT-88 11:35:10 |

| | | | |
|---|---|---|---|
| MODEL NAME: | WAGL12FT | LWL: | 4.69 FT |
| DISPLACEMENT: | 31.3 LBS | LCG: | 0.063 FT |
| WET SURFACE: | 4.4 SQ FT | STIM: | STUDS |
| WATER TEMP: | 67.5 F | | |

TOTAL MODEL RESISTANCE(RTM)

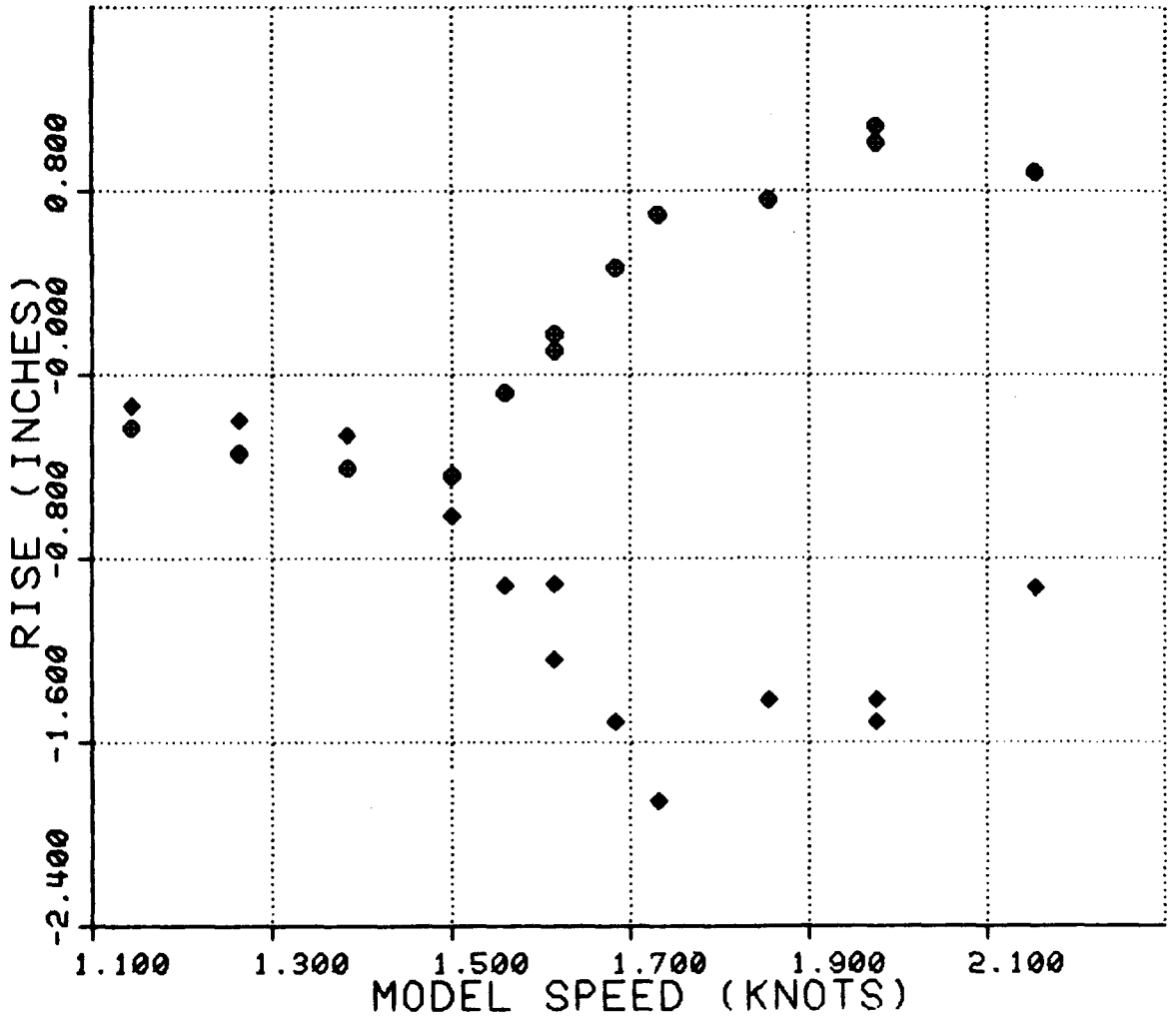


USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

TEST NO.: 451 START DATE: 03-OCT-88 09:17:51
TEST TYPE: EHP,SW ,120 PC LOG DATE: 04-OCT-88 11:35:19

MODEL NAME: WAGL12FT LWL: 4.69 FT
DISPLACEMENT: 31.3 LBS LCG: 0.063 FT
WET SURFACE: 4.4 SQ FT STIM: STUDS
WATER TEMP: 67.5 F

LEGEND: ⊕=FP RISE ◆=AP RISE

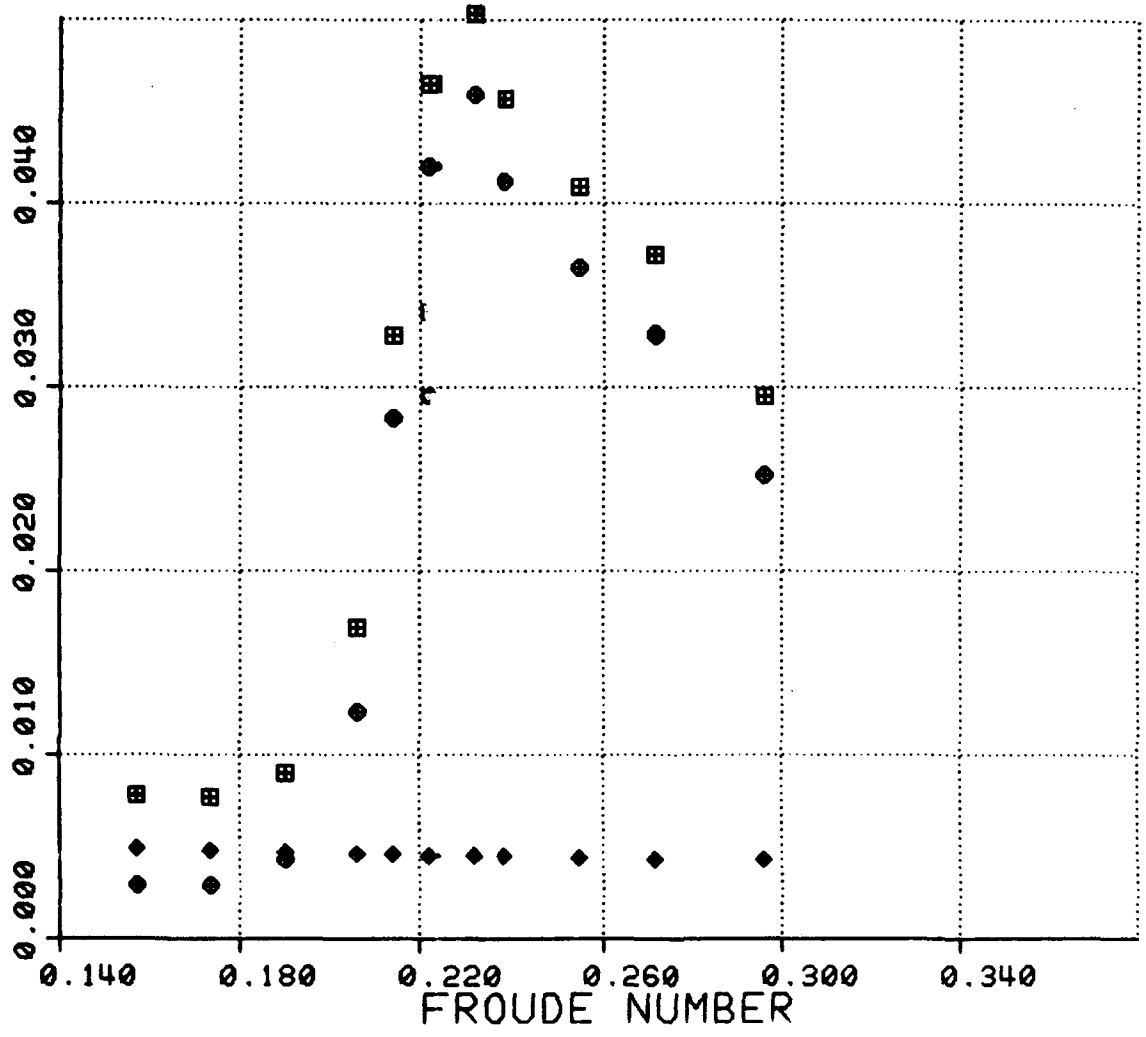


USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

TEST NO.: 451 START DATE: 03-OCT-88 09:17:51
TEST TYPE: EHP,SW ,120 PC LOG DATE: 04-OCT-88 11:35:19

MODEL NAME: WAGL12FT LWL: 4.69 FT
DISPLACEMENT: 31.3 LBS LCG: 0.063 FT
WET SURFACE: 4.4 SQ FT STIM: STUDS
WATER TEMP: 67.5 F

LEGEND: ⊞=CTM ◆=CFM ⊕=CRM



USNA HYDROMECHANICS LABORATORY

MODEL DATA TABULATION

TEST NO.: 452 TEST TYPE: EHP, STILL WATER, 12Ø, PC START DATE: Ø4-OCT-88 LOG DATE: Ø4-OCT-88, 14:38:4Ø

MODEL NAME: WAGL15FT LWL: 4.69Ø FT DISPLACEMENT: 31.3 LBS

WET SURFACE: 4.424 SQ FT LCG: Ø.Ø63 FT STIMULATOR: STUDS

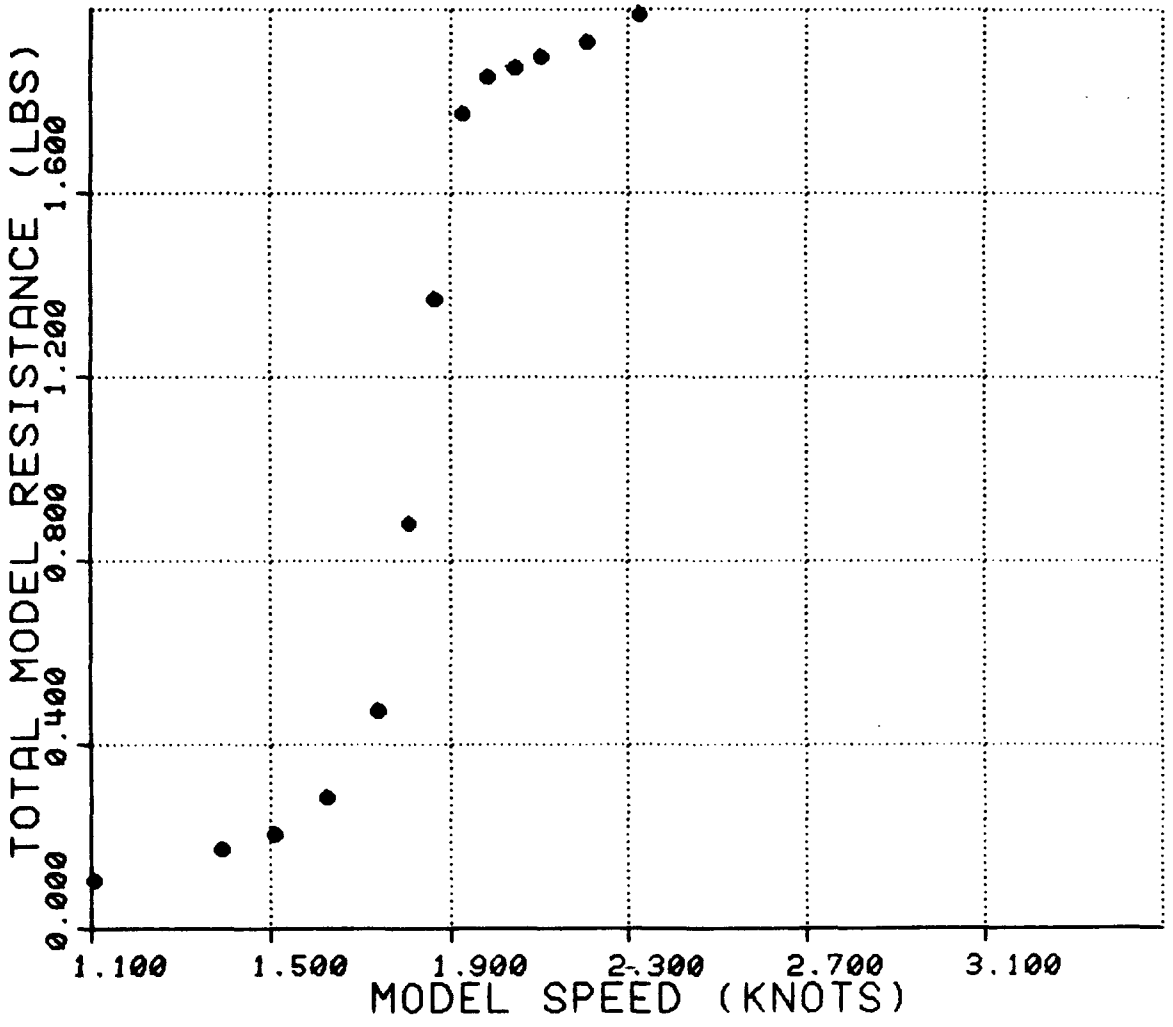
| RUN # | VM (KTS) | RTM (LBS) | FP RISE (FEET) | AP RISE (FEET) | TRIM (DEG) | FROUDE # | CTM - | RENLD # | CFM - | TEMP (F) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.1Ø6 | Ø.1Ø5 | -Ø.Ø14 | -Ø.ØØ5 | -Ø.11 | Ø.152 | Ø.7ØØ8E-Ø2 | Ø.8Ø47E+Ø6 | Ø.4917E-Ø2 | 67.5 |
| 2 | 1.624 | Ø.285 | -Ø.Ø37 | -Ø.Ø22 | -Ø.18 | Ø.223 | Ø.8837E-Ø2 | Ø.1182E+Ø7 | Ø.4522E-Ø2 | 67.5 |
| 3 | 1.5Ø9 | Ø.2Ø4 | -Ø.ØØ3Ø | -Ø.Ø14 | -Ø.19 | Ø.2Ø7 | Ø.7329E-Ø2 | Ø.1Ø98E+Ø7 | Ø.4593E-Ø2 | 67.5 |
| 4 | 1.392 | Ø.171 | -Ø.Ø23 | -Ø.Ø12 | -Ø.14 | Ø.191 | Ø.7231E-Ø2 | Ø.1Ø13E+Ø7 | Ø.4675E-Ø2 | 67.5 |
| 5 | 1.742 | Ø.47Ø | -Ø.Ø51 | -Ø.Ø44 | -Ø.Ø8 | Ø.239 | Ø.127ØE-Ø1 | Ø.1267E+Ø7 | Ø.4455E-Ø2 | 67.5 |
| 6 | 1.865 | 1.367 | -Ø.ØØ6 | -Ø.12Ø | 1.39 | Ø.256 | Ø.3222E-Ø1 | Ø.1357E+Ø7 | Ø.4392E-Ø2 | 67.5 |
| 7 | 1.983 | 1.853 | Ø.Ø14 | -Ø.Ø54 | Ø.82 | Ø.273 | Ø.3861E-Ø1 | Ø.1443E+Ø7 | Ø.4335E-Ø2 | 67.5 |
| 8 | 2.1Ø3 | 1.896 | Ø.Ø53 | -Ø.126 | 2.2Ø | Ø.289 | Ø.3514E-Ø1 | Ø.153ØE+Ø7 | Ø.4283E-Ø2 | 67.5 |
| 9 | 2.2Ø8 | 1.93Ø | Ø.Ø72 | -Ø.136 | 2.54 | Ø.3Ø4 | Ø.3242E-Ø1 | Ø.16Ø7E+Ø7 | Ø.424ØE-Ø2 | 67.5 |
| 1Ø | 2.Ø46 | 1.87Ø | Ø.Ø53 | -Ø.151 | 2.49 | Ø.281 | Ø.3662E-Ø1 | Ø.1489E+Ø7 | Ø.43Ø7E-Ø2 | 67.5 |
| 11 | 1.922 | 1.773 | Ø.ØØ7 | -Ø.Ø43 | Ø.61 | Ø.264 | Ø.3933E-Ø1 | Ø.1399E+Ø7 | Ø.4364E-Ø2 | 67.5 |
| 12 | 1.8Ø8 | Ø.882 | -Ø.Ø37 | -Ø.Ø79 | Ø.52 | Ø.248 | Ø.2211E-Ø1 | Ø.1316E+Ø7 | Ø.442ØE-Ø2 | 67.5 |
| 13 | 2.325 | 1.987 | Ø.Ø71 | -Ø.Ø9Ø | 1.98 | Ø.32Ø | Ø.3Ø12E-Ø1 | Ø.1692E+Ø7 | Ø.4195E-Ø2 | 67.5 |

USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

TEST NO.: 452 START DATE: 04-OCT-88 11:43:40
TEST TYPE: EHP,SW ,120 PC LOG DATE: 04-OCT-88 14:38:40

MODEL NAME: WAGL15FT LWL: 4.69 FT
DISPLACEMENT: 31.3 LBS LCG: 0.063 FT
WET SURFACE: 4.4 SQ FT STIM: STUDS
WATER TEMP: 67.5 F

TOTAL MODEL RESISTANCE(RTM)

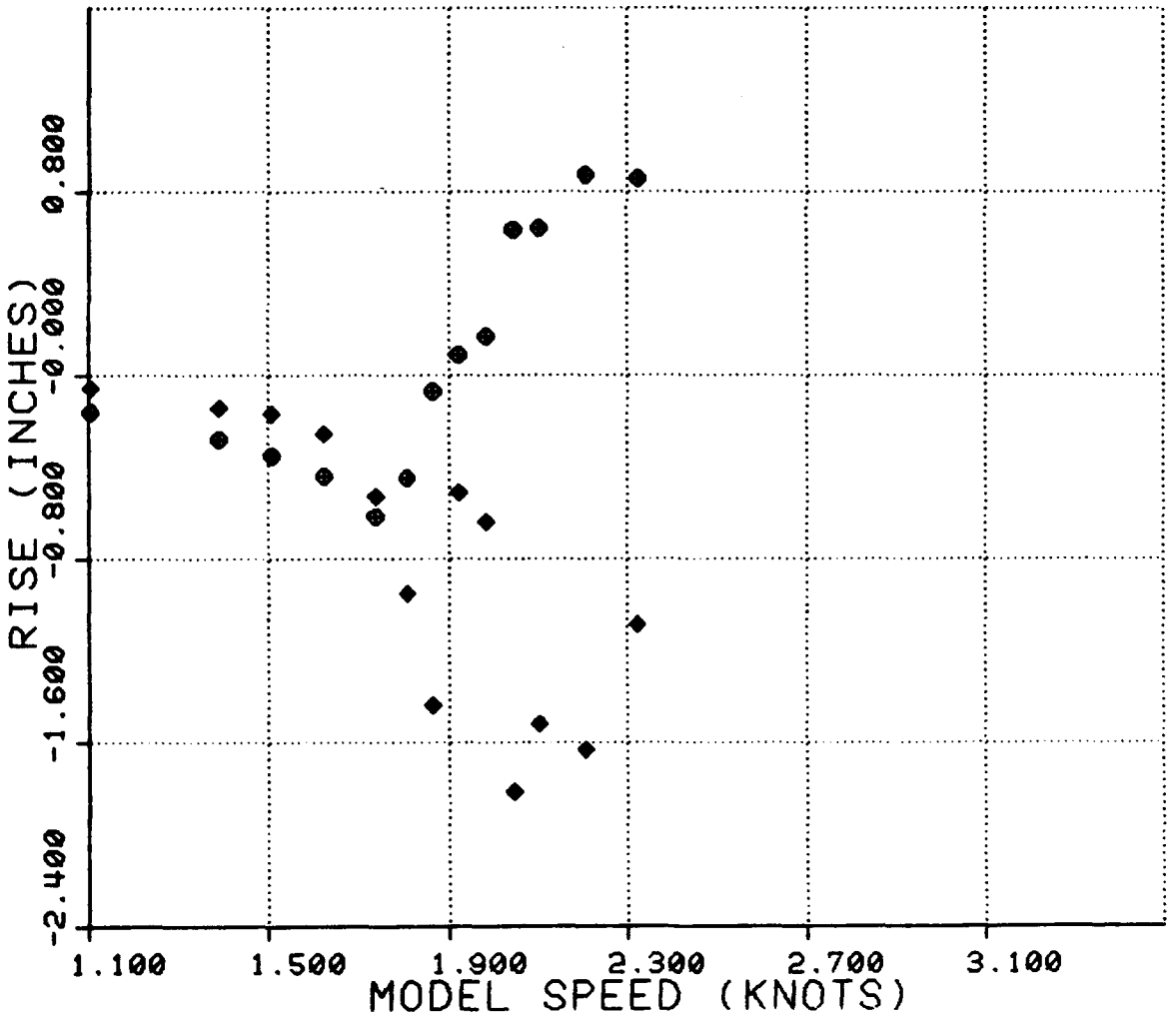


USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

TEST NO.: 452 START DATE: 04-OCT-88 11:43:40
TEST TYPE: EHP,SW ,120 PC LOG DATE: 04-OCT-88 14:38:40

MODEL NAME: WAGL15FT LWL: 4.69 FT
DISPLACEMENT: 31.3 LBS LCG: 0.063 FT
WET SURFACE: 4.4 SQ FT STIM: STUDS
WATER TEMP: 67.5 F

LEGEND: ●-FP RISE ◆-AP RISE

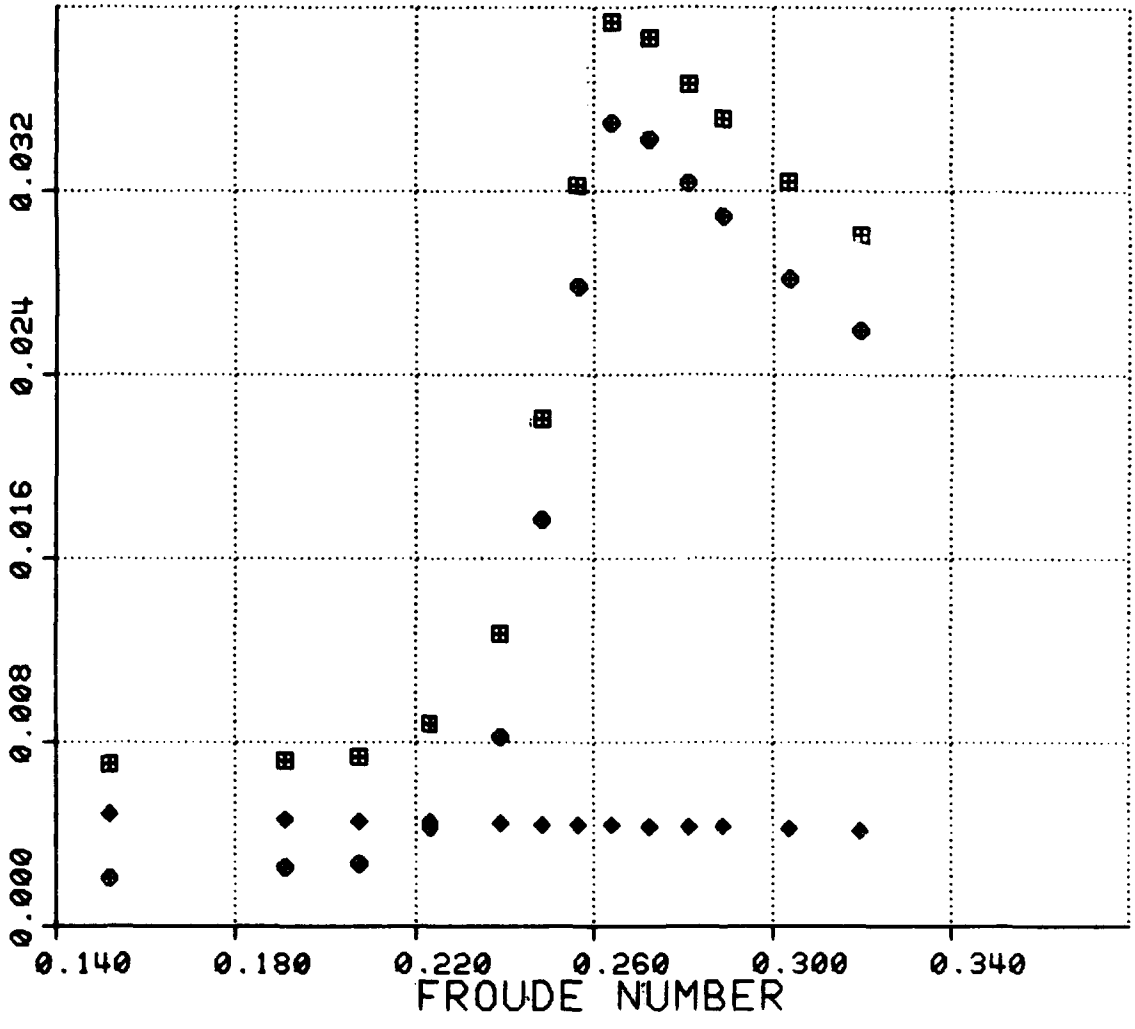


USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

TEST NO.: 452 START DATE: 04-OCT-88 11:43:40
TEST TYPE: EHP,SW ,120 PC LOG DATE: 04-OCT-88 14:38:40

MODEL NAME: WAGL15FT LWL: 4.69 FT
DISPLACEMENT: 31.3 LBS LCG: 0.063 FT
WET SURFACE: 4.4 SQ FT STIM: STUDS
WATER TEMP: 67.5 F

LEGEND: ⊞ =CTM ◆ =CFM ⊕ =CRM



## APPENDIX B

### REGULAR WAVE TEST DATA

- TST 135 - Long Crested, Head Seas
  - $\overline{V}_s$ = 2.45 fps
  - $\overline{V}_m$ = 3.65 fps

- TST 322 - Long Crested, Head Seas
  - $\overline{V}_m$ = 3.05 fps

USNA HYDROMECHANICS LABORATORY

MODEL DATA TABULATION

TEST NO.: 135 TEST TYPE: EHP, REGULAR WAVES, 12Ø, PC START DATE: Ø4-FEB-87 LOG DATE: 27-OCT-88, Ø8:49:18

MODEL NAME: WAGL LWL: 4.69Ø FT DISPLACEMENT: 31.3 LBS

WET SURFACE: 4.424 SQ FT LCG: Ø.Ø63 FT STIMULATOR: STUDS

PITCH GYRADIUS: 1.17 FT WATER TEMP: 65.Ø (F) WAVE DIRECTION: 18Ø. DEG

NO. OF PROPS: NONE SUBTEST VELOCITY: 1.422 (KTS) WAVE SENSOR TO AMIDSHIPS: 2.ØØ FT

FROUDE NO.: Ø.195

| RUN # | AVG SPEED (KTS) | AVG RTMW (LBS) | AVG CTMW - | TRIM (DEG) - | CG RISE (IN) - | FE (HZ) - | AMP (TOT PWR) (FT) | AMP (FOURIER) (FT) | LW/LM - - |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.452 | Ø.238 | Ø.9255E-Ø2 | -Ø.Ø48 | -Ø.ØØ7 | 1.479 | Ø.Ø38 | Ø.Ø36 | 1.Ø91 |
| 2 | 1.452 | Ø.143 | Ø.5569E-Ø2 | -Ø.Ø64 | -Ø.ØØ8 | Ø.559 | Ø.166 | Ø.165 | 4.774 |
| 3 | 1.453 | Ø.229 | Ø.8881E-Ø2 | -Ø.179 | -Ø.ØØ4 | Ø.776 | Ø.151 | Ø.151 | 2.966 |
| 4 | 1.451 | Ø.225 | Ø.8749E-Ø2 | -Ø.11Ø | Ø.ØØ4 | Ø.936 | Ø.Ø94 | Ø.Ø94 | 2.216 |
| 5 | 1.451 | Ø.246 | Ø.9575E-Ø2 | -Ø.Ø58 | -Ø.ØØ1 | 1.196 | Ø.Ø71 | Ø.Ø71 | 1.7Ø4 |
| 6 | 1.45Ø | Ø.279 | Ø.1Ø86E-Ø1 | -Ø.Ø62 | -Ø.ØØ7 | 1.287 | Ø.Ø56 | Ø.Ø55 | 1.347 |
| 7 | 1.452 | Ø.282 | Ø.1Ø94E-Ø1 | -Ø.Ø51 | -Ø.Ø12 | 1.479 | Ø.Ø47 | Ø.Ø44 | 1.Ø91 |
| 8 | 1.45. | Ø.224 | Ø.8726E-Ø2 | -Ø.Ø75 | -Ø.Ø15 | 1.679 | Ø.Ø41 | Ø.Ø39 | Ø.9Ø2 |
| 9 | 1.449 | Ø.182 | Ø.71ØØE-Ø2 | -Ø.Ø94 | -Ø.ØØ1 | 1.898 | Ø.Ø36 | Ø.Ø33 | Ø.75Ø |

TEST NO.: 135 TEST TYPE: EHP, REGULAR WAVES, 12Ø, PC START DATE: Ø4-FEB-87 LOG DATE: 27-OCT-88, Ø8:49:18

MODEL NAME: WAGL
WET SURFACE: 4.424 SQ FT
PITCH GYRADIUS: 1.17 FT
NO. OF PROPS: NONE

LWL: 4.69Ø FT
LCG: Ø.Ø63 FT
WATER TEMP: 65.Ø (F)
SUBTEST VELOCITY: 1.422 (KTS)
FROUDE NO.: Ø.195

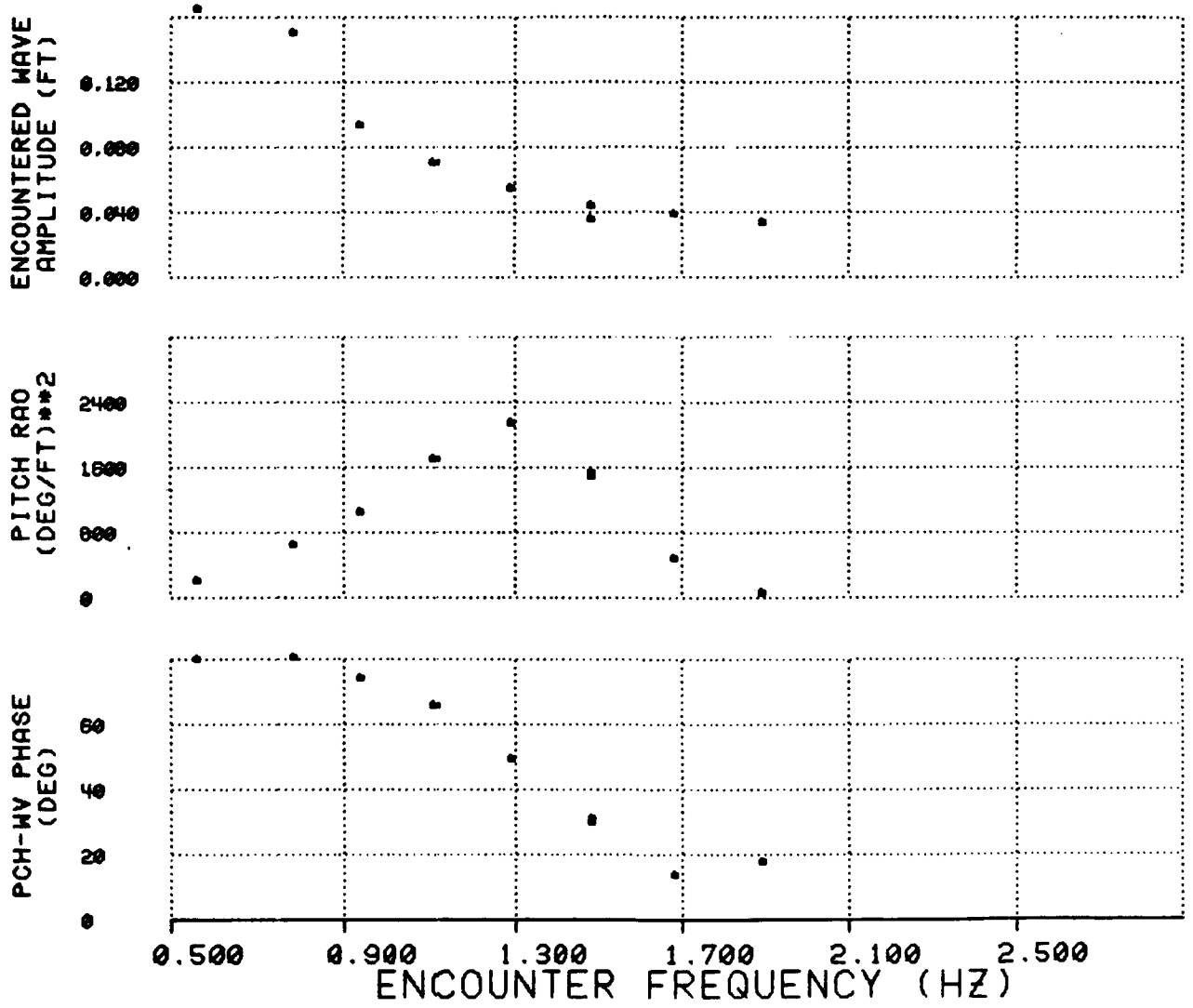
DISPLACEMENT: 31.3 LBS
STIMULATOR: STUDS
WAVE DIRECTION: 18Ø. DEG
WAVE SENSOR TO AMIDSHIPS: 2.ØØ FT

| RUN # | AVG SPEED (KTS) | FE (HZ) | AMP (FUR) (FT) | PITCH RAO (DEG/FT)**2 | PCH-WV PHASE (DEG) | HEAVE RAO (FT/FT)**2 | HV-WV PHASE (DEG) | SURGE RAO (FT/FT)**2 | SUR-WV PHASE (DEG) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.453 | 1.479 | Ø.ØØ36 | Ø.156E+Ø4 | 3Ø.97 | Ø.264E+ØØ | 1.ØØ | | |
| 2 | 1.452 | Ø.559 | Ø.165 | Ø.231E+Ø3 | 6Ø.ØØ | Ø.922E+ØØ | -3.11 | | |
| 3 | 1.453 | Ø.776 | Ø.151 | Ø.657E+Ø3 | 8Ø.47 | Ø.828E+ØØ | -1.99 | | |
| 4 | 1.451 | Ø.936 | Ø.Ø94 | Ø.1Ø5E+Ø4 | 74.31 | Ø.7Ø5E+ØØ | -1.91 | | |
| 5 | 1.451 | 1.1Ø6 | Ø.Ø71 | Ø.171E+Ø4 | 65.96 | Ø.548E+ØØ | -1.49 | | |
| 6 | 1.45Ø | 1.287 | Ø.Ø55 | Ø.215E+Ø4 | 49.44 | Ø.382E+ØØ | -1.11 | | |
| 7 | 1.452 | 1.479 | Ø.Ø44 | Ø.149E+Ø4 | 29.76 | Ø.234E+ØØ | 3.49 | | |
| 8 | 1.451 | 1.679 | Ø.Ø39 | Ø.497E+Ø3 | 13.63 | Ø.1Ø6E+ØØ | -3.42 | | |
| 9 | 1.449 | 1.888 | Ø.Ø33 | Ø.747E+Ø2 | 18.15 | Ø.296E-Ø1 | 2Ø.46 | | |

USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

| | |
|---|---|
| TEST NO.: 135 | START DATE: 04-FEB-87 15:28:59 |
| TEST TYPE: EHP,RW ,120 PC | LOG DATE: 27-OCT-88 08:49:18 |

| | | | |
|---|---|---|---|
| MODEL NAME: | WAGL | LWL: | 4.69 FT |
| DISPLACEMENT: | 31.3 LBS | LCG: | 0.063 FT |
| WET SURFACE: | 4.4 SQ FT | STIM: | STUDS |
| PITCH GYRADIUS: | 1.17 FT | WATER TEMP: | 65.0(F) |
| SUBTEST VEL.: | 1.422 KTS | WAVE DIRECTION: | 180 DEG |
| FROUDE NO.: | 0.185 | NO. OF PROPS: | 0 |
| WAVE SENSOR TO AMID.: | 2.00 FT | | |



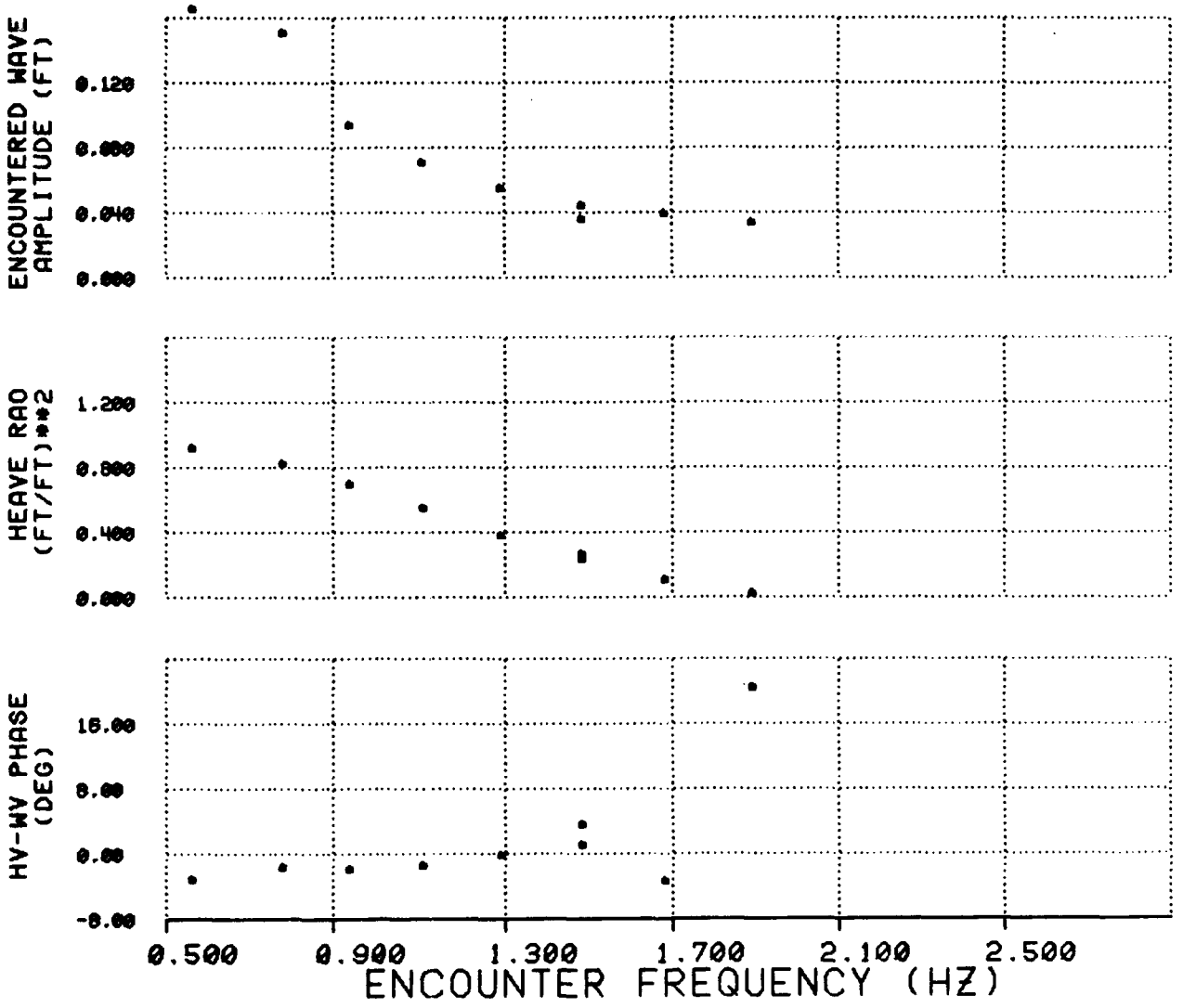
USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

TEST NO.: 135
TEST TYPE: EHP,RW ,120 PC

START DATE: 04-FEB-87 15:28:59
LOG DATE: 27-OCT-88 08:49:18

MODEL NAME: WAGL
DISPLACEMENT: 31.3 LBS
WET SURFACE: 4.4 SQ FT
PITCH GYRADIUS: 1.17 FT
SUBTEST VEL.: 1.422 KTS
FROUDE NO.: 0.195
WAVE SENSOR TO AMID.: 2.00 FT

LWL: 4.69 FT
LCG: 0.063 FT
STIM: STUDS
WATER TEMP: 65.0(F)
WAVE DIRECTION: 180 DEG
NO. OF PROPS: 0



USNA HYDROMECHANICS LABORATORY

MODEL DATA TABULATION

TEST NO.: 135 TEST TYPE: EHP, REGULAR WAVES, 12Ø, PC START DATE: Ø4-FEB-87 LOG DATE: 27-OCT-88, Ø8:52:17

MODEL NAME: WAGL LWL: 4.69Ø FT DISPLACEMENT: 31.3 LBS

WET SURFACE: 4.424 SQ FT LCG: Ø.Ø63 FT STIMULATOR: STUDS

PITCH GYRADIUS: 1.17 FT WATER TEMP: 65.Ø (F) WAVE DIRECTION: 18Ø. DEG

NO. OF PROPS: NONE SUBTEST VELOCITY: 2.133 (KTS) WAVE SENSOR TO AMIDSHIPS: 2.ØØ FT

FROUDE NO.: Ø.293

| RUN # | AVG SPEED (KTS) | AVG RTMW (LBS) | AVG CTMW - | TRIM (DEG) - | CG RISE (IN) - | FE (HZ) - | AMP (TOT PWR) (FT) | AMP (FOURIER) (FT) | LW/LM - |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.162 | Ø.518 | Ø.9Ø87E-Ø2 | -Ø.128 | -Ø.Ø16 | Ø.613 | Ø.166 | Ø.165 | 4.774 |
| 2 | 2.167 | Ø.586 | Ø.1Ø22E-Ø1 | -Ø.171 | -Ø.Ø19 | Ø.775 | Ø.137 | Ø.137 | 3.46Ø |
| 3 | 2.163 | Ø.632 | Ø.11Ø6E-Ø1 | -Ø.211 | -Ø.Ø18 | Ø.955 | Ø.1Ø6 | Ø.1Ø6 | 2.585 |
| 4 | 2.164 | Ø.653 | Ø.1141E-Ø1 | -Ø.191 | -Ø.Ø25 | 1.152 | Ø.Ø82 | Ø.Ø81 | 1.936 |
| 5 | 2.162 | Ø.731 | Ø.1281E-Ø1 | -Ø.172 | -Ø.Ø28 | 1.365 | Ø.Ø63 | Ø.Ø63 | 1.51Ø |
| 6 | 2.166 | Ø.715 | Ø.1248E-Ø1 | -Ø.131 | -Ø.Ø13 | 1.595 | Ø.Ø53 | Ø.Ø52 | 1.2Ø9 |
| 7 | 2.162 | Ø.63Ø | Ø.11Ø5E-Ø1 | -Ø.176 | -Ø.Ø17 | 1.836 | Ø.Ø44 | Ø.Ø42 | Ø.99Ø |
| 8 | 2.164 | Ø.584 | Ø.1Ø22E-Ø1 | -Ø.191 | -Ø.Ø21 | 2.Ø94 | Ø.Ø41 | Ø.Ø4Ø | Ø.825 |

TEST NO.: 135 TEST TYPE: EHP, REGULAR WAVES, 12#, PC START DATE: #4-FEB-87 LOG DATE: 27-OCT-88, #8:52:17

MODEL NAME: WAGL
WET SURFACE: 4.424 SQ FT
PITCH GYRADIUS: 1.17 FT
NO. OF PROPS: NONE

LWL: 4.69# FT
LCG: #.#63 FT
WATER TEMP: 65.# (F)
SUBTEST VELOCITY: 2.133 (KTS)
FROUDE NO.: #.293

DISPLACEMENT: 31.3 LBS
STIMULATOR: STUDS
WAVE DIRECTION: 18#. DEG
WAVE SENSOR TO AMIDSHIPS: 2.## FT

| RUN # | AVG SPEED (KTS) | FE (HZ) | AMP (FUR) (FT) | PITCH RAO (DEG/FT)**2 | PCH-WV PHASE (DEG) | HEAVE RAO (FT/FT)**2 | HV-WV PHASE (DEG) | SURGE RAO (FT/FT)**2 | SUR-WV PHASE (DEG) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.162 | #.613 | #.165 | #.215E+#3 | 83.75 | #.979E+## | -2.2# | | |
| 2 | 2.167 | #.775 | #.137 | #.467E+#3 | 79.27 | #.925E+## | -2.62 | | |
| 3 | 2.163 | #.955 | #.1#6 | #.92#E+#3 | 73.69 | #.873E+## | -3.7# | | |
| 4 | 2.164 | 1.152 | #.#81 | #.171E+#4 | 62.31 | #.793E+## | -3.48 | | |
| 5 | 2.162 | 1.365 | #.#63 | #.248E+#4 | 4#.#2 | #.795E+## | -9.69 | | |
| 6 | 2.166 | 1.595 | #.#52 | #.178E+#4 | 11.78 | #.689E+## | -29.52 | | |
| 7 | 2.162 | 1.836 | #.#42 | #.643E+#3 | -7.23 | #.174E+## | -4#.67 | | |
| 8 | 2.164 | 2.#94 | #.#4# | #.874E+#2 | -22.51 | #.192E-#1 | -34.37 | | |

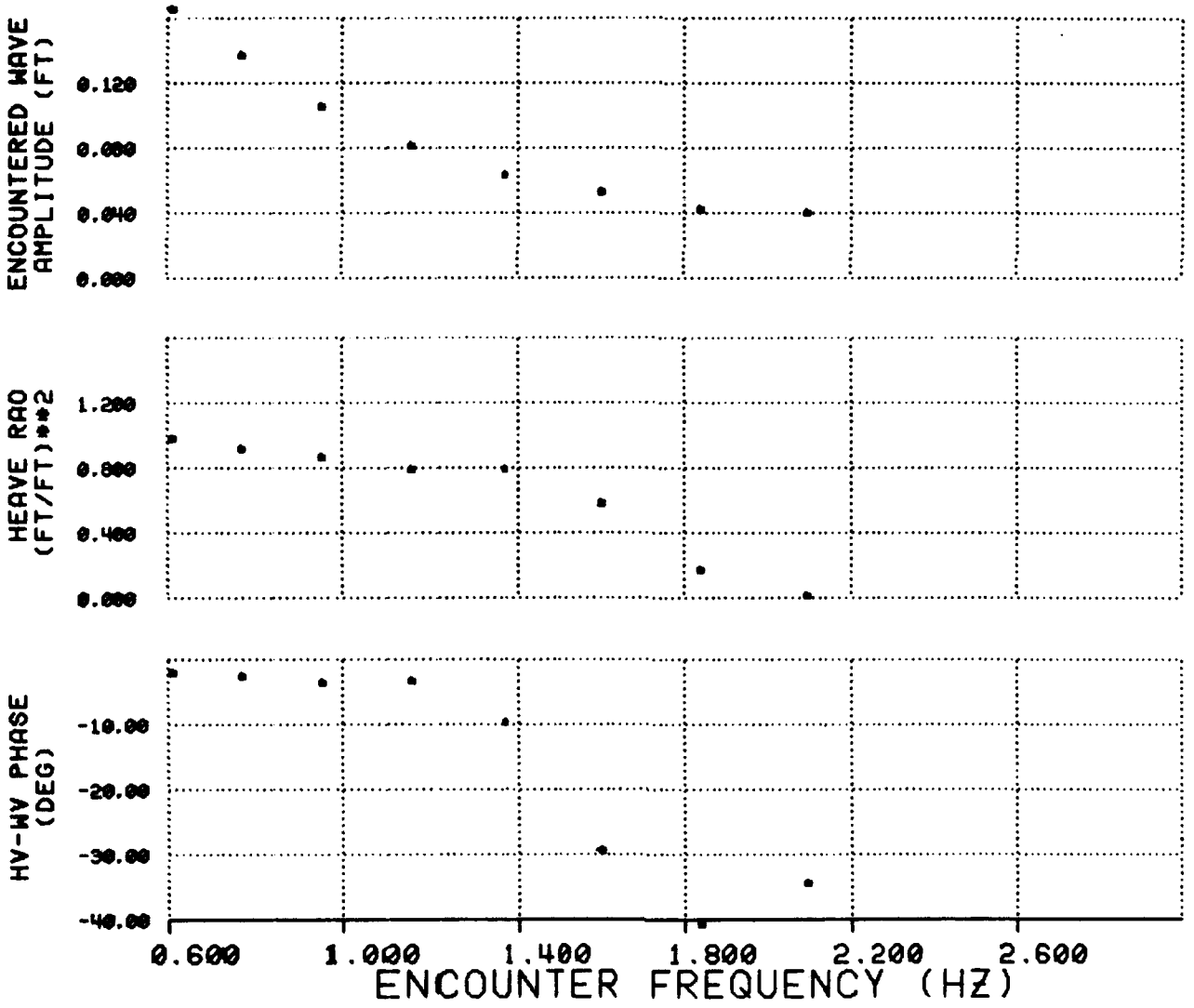
USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

TEST NO.: 135
TEST TYPE: EHP,RW ,120 PC

START DATE: 04-FEB-87 15:28:59
LOG DATE: 27-OCT-88 08:52:17

MODEL NAME: WAGL
DISPLACEMENT: 31.3 LBS
WET SURFACE: 4.4 SQ FT
PITCH GYRADIUS: 1.17 FT
SUBTEST VEL.: 2.133 KTS
FROUDE NO.: 0.293
WAVE SENSOR TO AMID.: 2.00 FT

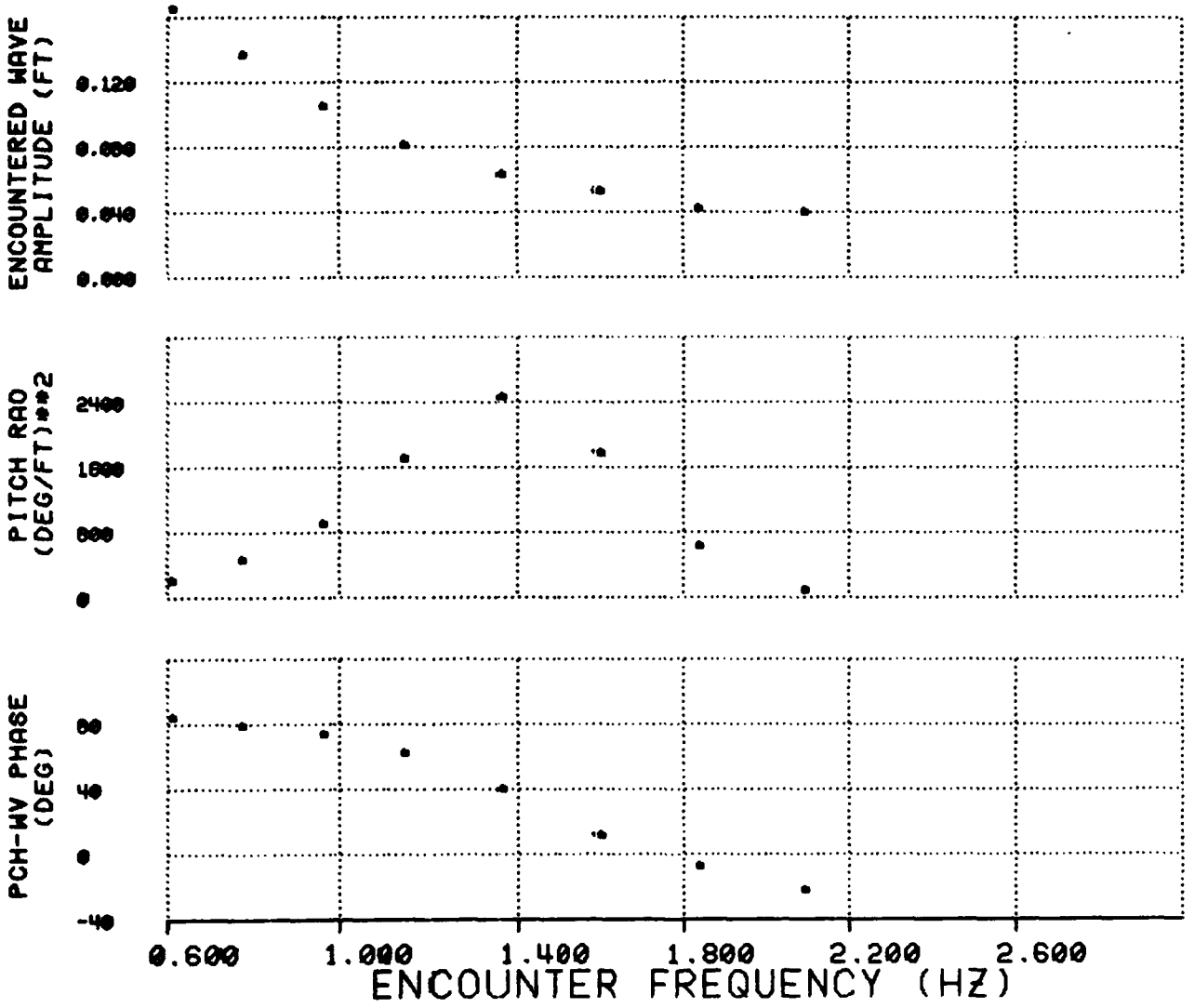
LWL: 4.69 FT
LCG: 0.063 FT
STIM: STUDS
WATER TEMP: 65.0(F)
WAVE DIRECTION: 180 DEG
NO. OF PROPS: 0



USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

| | |
|---|---|
| TEST NO.: 135 | START DATE: 04-FEB-87 15:28:59 |
| TEST TYPE: EHP,RW ,120 PC | LOG DATE: 27-OCT-88 08:52:17 |

| | |
|---|---|
| MODEL NAME: WAGL | LWL: 4.69 FT |
| DISPLACEMENT: 31.3 LBS | LCG: 0.063 FT |
| WET SURFACE: 4.4 SQ FT | STIM: STUDS |
| PITCH GYRADIUS: 1.17 FT | WATER TEMP: 65.0(F) |
| SUBTEST VEL.: 2.133 KTS | WAVE DIRECTION: 180 DEG |
| FROUDE NO.: 0.203 | NO. OF PROPS: 0 |
| WAVE SENSOR TO AMID.: 2.00 FT | |



USNA HYDROMECHANICS LABORATORY

MODEL DATA TABULATION

TEST NO.: 322 TEST TYPE: EHP, REGULAR WAVES, 12Ø, PC START DATE: 19-DEC-89 LOG DATE: 22-MAY-9Ø, 1Ø:Ø8:28

MODEL NAME: WAGL LWL: 4.69Ø FT DISPLACEMENT: 31.3 LBS

WET SURFACE: 4.424 SQ FT LCG: Ø.Ø63 FT STIMULATOR: STUDS

PITCH GYRADIUS: 1.17 FT WATER TEMP: 63.5 (F) WAVE DIRECTION: 18Ø. DEG

NO. OF PROPS: NONE SUBTEST VELOCITY: 1.777 (KTS) WAVE SENSOR TO AMIDSHIPS: 2.ØØ FT

FROUDE NO.: Ø.244

| RUN # | AVG SPEED (KTS) | AVG RTMW (LBS) | AVG CTMW - | TRIM (DEG) - | CG RISE (IN) - | FE (HZ) - | AMP (TOT PWR) (FT) | AMP (FOURIER) (FT) | LW/LM - - |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.8Ø9 | Ø.374 | Ø.9355E-Ø2 | -Ø.Ø96 | -Ø.Ø11 | 1.597 | Ø.Ø4Ø | Ø.Ø38 | 1.Ø91 |
| 2 | 1.8ØØ | Ø.314 | Ø.7932E-Ø2 | -Ø.Ø45 | Ø.ØØ2 | Ø.586 | Ø.162 | Ø.16Ø | 4.774 |
| 3 | 1.81Ø | Ø.311 | Ø.7771E-Ø2 | -Ø.Ø58 | -Ø.ØØ6 | Ø.661 | Ø.148 | Ø.147 | 4.Ø55 |
| 4 | 1.816 | Ø.245 | Ø.6Ø87E-Ø2 | -Ø.243 | -Ø.ØØ8 | Ø.82Ø | Ø.117 | Ø.116 | 2.966 |
| 5 | 1.8Ø5 | Ø.317 | Ø.7961E-Ø2 | -Ø.16Ø | -Ø.ØØ2 | Ø.993 | Ø.Ø93 | Ø.Ø92 | 2.216 |
| 6 | 1.811 | Ø.352 | Ø.8782E-Ø2 | -Ø.142 | -Ø.ØØØ | 1.183 | Ø.Ø7Ø | Ø.Ø69 | 1.7Ø4 |
| 7 | 1.8Ø9 | Ø.377 | Ø.9439E-Ø2 | -Ø.129 | Ø.ØØØ | 1.383 | Ø.Ø51 | Ø.Ø5Ø | 1.347 |
| 8 | 1.8Ø9 | Ø.3Ø4 | Ø.7597E-Ø2 | -Ø.17Ø | -Ø.ØØ9 | 1.822 | Ø.Ø38 | Ø.Ø38 | Ø.9Ø2 |
| 9 | 1.8Ø9 | Ø.377 | Ø.9425E-Ø2 | -Ø.121 | -Ø.Ø14 | 1.488 | Ø.Ø46 | Ø.Ø45 | 1.2Ø9 |
| 1Ø | 1.81Ø | Ø.379 | Ø.9466E-Ø2 | -Ø.124 | -Ø.ØØ5 | 1.281 | Ø.Ø6Ø | Ø.Ø59 | 1.51Ø |
| 11 | 1.81Ø | Ø.4Ø1 | Ø.1ØØ1E-Ø1 | -Ø.1Ø7 | -Ø.Ø1Ø | 1.332 | Ø.Ø59 | Ø.Ø58 | 1.425 |
| 12 | 1.8Ø9 | Ø.39Ø | Ø.9763E-Ø2 | -Ø.Ø99 | -Ø.Ø16 | 1.435 | Ø.Ø49 | Ø.Ø49 | 1.275 |
| 13 | 1.81Ø | Ø.352 | Ø.88ØØE-Ø2 | -Ø.151 | -Ø.ØØ6 | 1.232 | Ø.Ø62 | Ø.Ø62 | 1.6Ø2 |
| 14 | 1.8Ø9 | Ø.334 | Ø.8351E-Ø2 | -Ø.1Ø6 | -Ø.Ø11 | 1.Ø86 | Ø.Ø79 | Ø.Ø78 | 1.936 |
| 15 | 1.8Ø9 | Ø.285 | Ø.7138E-Ø2 | -Ø.152 | -Ø.Ø16 | Ø.9Ø5 | Ø.1Ø4 | Ø.1Ø3 | 2.555 |

TEST NO.: 322 TEST TYPE: EHP, REGULAR WAVES, 12Ø, PC START DATE: 19-DEC-89 LOG DATE: 22-MAY-9Ø, 1Ø:Ø8:28

MODEL NAME: WAGL
WET SURFACE: 4.424 SQ FT
PITCH GYRADIUS: 1.17 FT
NO. OF PROPS: NONE

LWL: 4.69Ø FT
LCG: Ø.Ø63 FT
WATER TEMP: 63.5 (F)
SUBTEST VELOCITY: 1.777 (KTS)
FROUDE NO.: Ø.244

DISPLACEMENT: 31.3 LBS
STIMULATOR: STUDS
WAVE DIRECTION: 18Ø. DEG
WAVE SENSOR TO AMIDSHIPS: 2.ØØ FT

| RUN # | AVG SPEED (KTS) | AVG RTMW (LBS) | AVG CTMW - | TRIM (DEG) - | CG RISE (IN) - | FE (HZ) - | AMP (TOT PWR) (FT) | AMP (FOURIER) (FT) | LW/LM - - |
|---|---|---|---|---|---|---|---|---|---|
| 16 | 1.81Ø | Ø.277 | Ø.6921E-Ø2 | -Ø.139 | -Ø.ØØ6 | Ø.738 | Ø.135 | Ø.134 | 3.46Ø |
| 17 | 1.81Ø | Ø.31Ø | Ø.7762E-Ø2 | -Ø.159 | -Ø.Ø1Ø | 1.7Ø8 | Ø.Ø37 | Ø.Ø36 | Ø.99Ø |
| 18 | 1.81Ø | Ø.338 | Ø.8456E-Ø2 | -Ø.123 | -Ø.Ø17 | 1.134 | Ø.Ø75 | Ø.Ø75 | 1.814 |
| 19 | 1.81Ø | Ø.371 | Ø.9277E-Ø2 | -Ø.1Ø7 | -Ø.Ø1Ø | 1.543 | Ø.Ø45 | Ø.Ø45 | 1.148 |

TEST NO.: 322 TEST TYPE: EHP, REGULAR WAVES, 12Ø, °C START DATE: 19-DEC-89 LOG DATE: 22-MAY-9Ø, 1Ø:Ø8:28

MODEL NAME: WAGL
WET SURFACE: 4.424 SQ FT
PITCH GYRADIUS: 1.17 FT
NO. OF PROPS: NONE

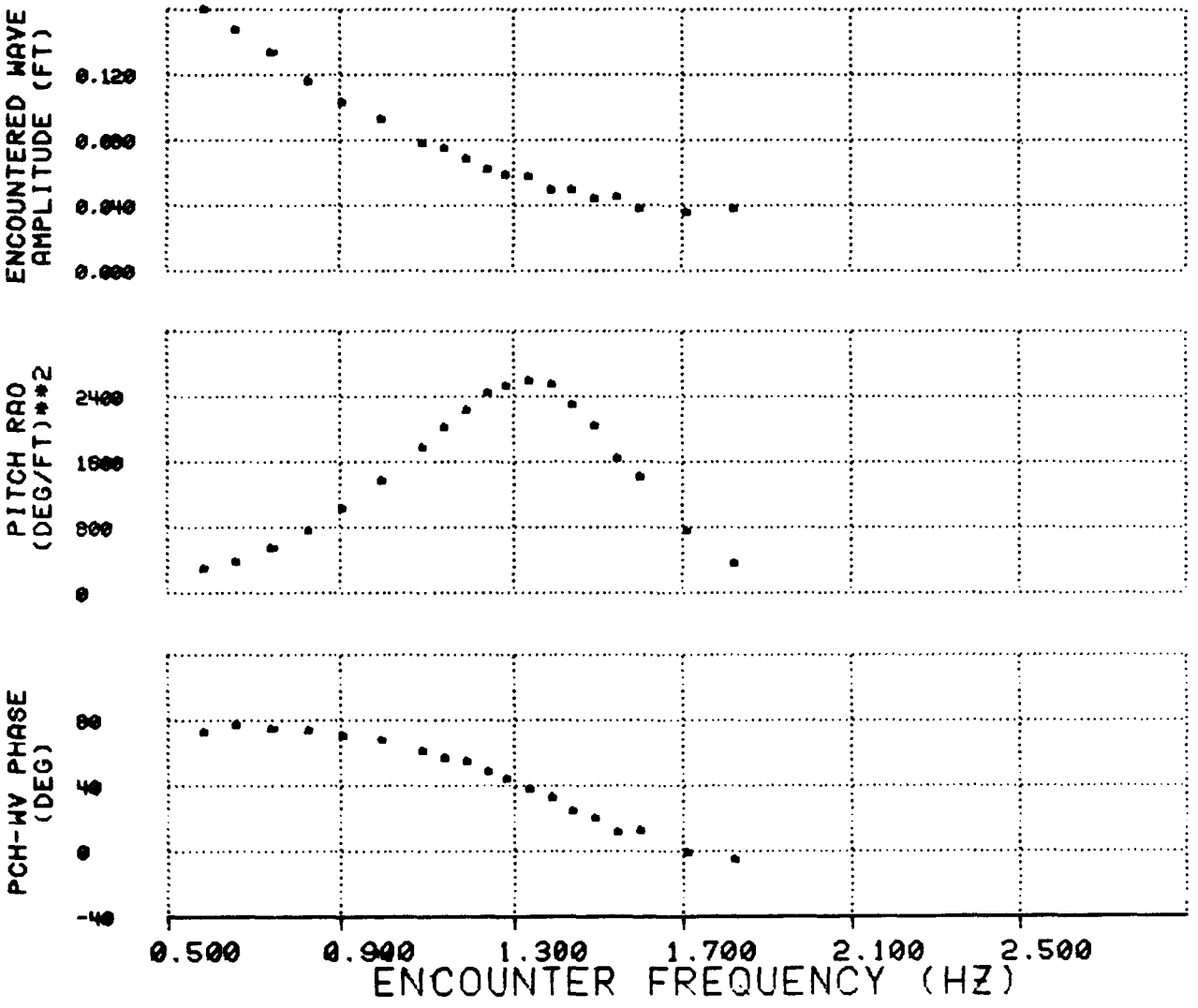
LWL: 4.69Ø FT
LCG: Ø.Ø63 FT
WATER TEMP: 63.5 (F)
SUBTEST VELOCITY: 1.777 (KTS)
FROUDE NO.: Ø.244

DISPLACEMENT: 31.3 LBS
STIMULATOR: STUDS
WAVE DIRECTION: 18Ø. DEG
WAVE SENSOR TO AMIDSHIPS: 2.ØØ FT

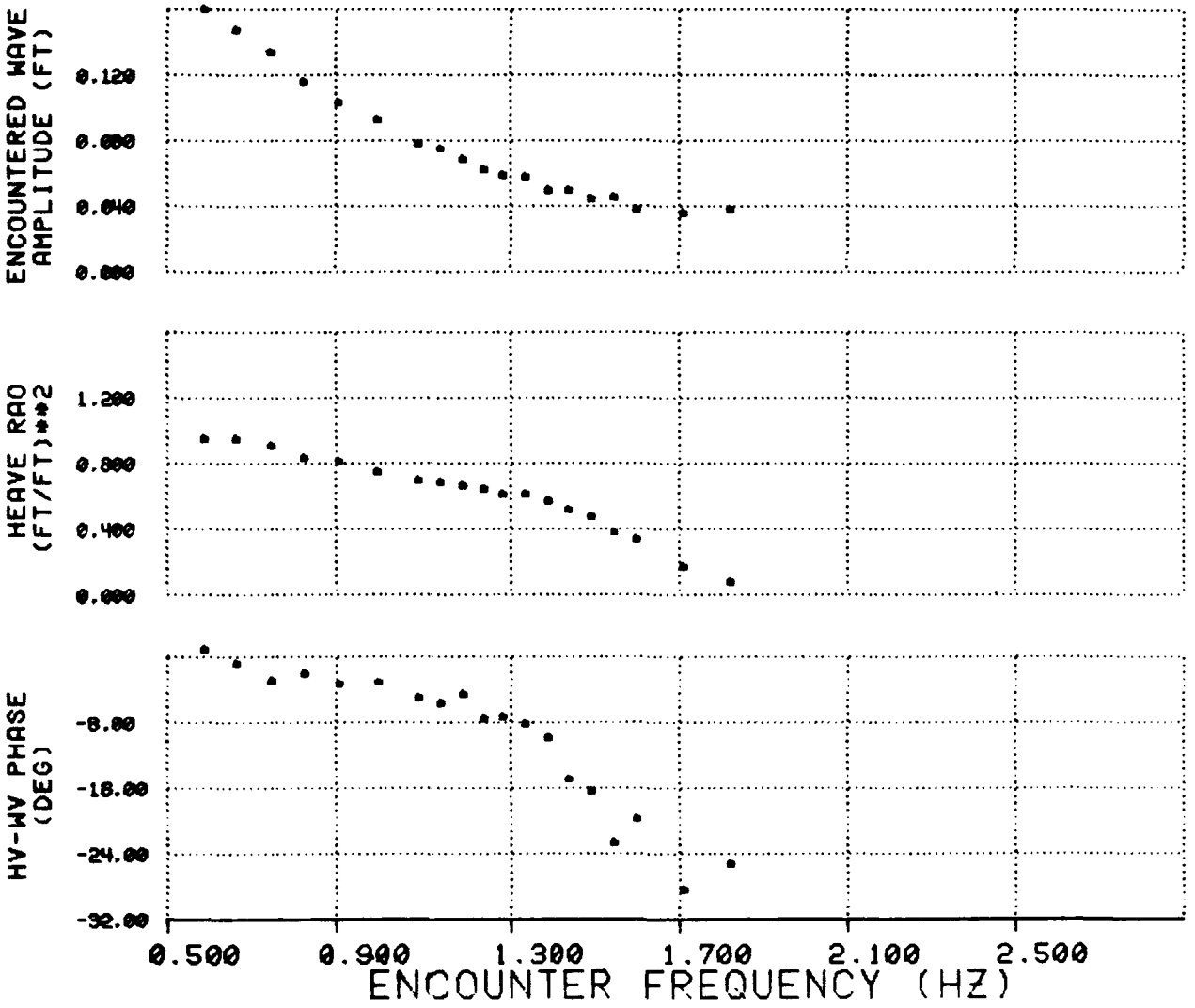
| RUN # | AVG SPEED (KTS) | FE (HZ) | AMP (FUR) (FT) | PITCH RAO (DEG/FT)**2 | PCH-WV PHASE (DEG) | HEAVE RAO (FT/FT)**2 | HV-WV PHASE (DEG) | SURGE RAO (FT/FT)**2 | SUR-WV PHASE (DEG) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.8Ø9 | 1.597 | Ø.Ø38 | Ø.143E+Ø4 | 12.98 | Ø.341E+ØØ | -19.77 | | |
| 2 | 1.8ØØ | Ø.586 | Ø.16Ø | Ø.3Ø7E+Ø3 | 72.55 | Ø.947E+ØØ | Ø.74 | | |
| 3 | 1.81Ø | Ø.661 | Ø.147 | Ø.387E+Ø3 | 76.72 | Ø.954E+ØØ | -Ø.85 | | |
| 4 | 1.816 | Ø.82Ø | Ø.116 | Ø.766E+Ø3 | 73.64 | Ø.841E+ØØ | -2.17 | | |
| 5 | 1.8Ø5 | Ø.993 | Ø.Ø92 | Ø.137E+Ø4 | 67.3Ø | Ø.755E+ØØ | -3.25 | | |
| 6 | 1.811 | 1.183 | Ø.Ø69 | Ø.224E+Ø4 | 54.51 | Ø.663E+ØØ | -4.71 | | |
| 7 | 1.8Ø9 | 1.383 | Ø.Ø5Ø | Ø.256E+Ø4 | 32.37 | Ø.578E+ØØ | -9.89 | | |
| 8 | 1.8Ø9 | 1.822 | Ø.Ø38 | Ø.364E+Ø3 | -4.88 | Ø.8Ø9E-Ø1 | -25.31 | | |
| 9 | 1.8Ø9 | 1.488 | Ø.Ø45 | Ø.2Ø5E+Ø4 | 19.91 | Ø.476E+ØØ | -16.34 | | |
| 1Ø | 1.81Ø | 1.281 | Ø.Ø59 | Ø.254E+Ø4 | 43.9Ø | Ø.611E+ØØ | -7.27 | | |
| 11 | 1.81Ø | 1.332 | Ø.Ø58 | Ø.261E+Ø4 | 38.Ø2 | Ø.613E+ØØ | -8.28 | | |
| 12 | 1.8Ø9 | 1.435 | Ø.Ø49 | Ø.231E+Ø4 | 24.Ø9 | Ø.523E+ØØ | -15.Ø1 | | |
| 13 | 1.81Ø | 1.232 | Ø.Ø62 | Ø.246E+Ø4 | 48.Ø3 | Ø.646E+ØØ | -7.55 | | |
| 14 | 1.8Ø9 | 1.Ø86 | Ø.Ø78 | Ø.178E+Ø4 | 61.15 | Ø.696E+ØØ | -5.Ø5 | | |
| 15 | 1.8Ø9 | Ø.9Ø5 | Ø.1Ø3 | Ø.1Ø3E+Ø4 | 7Ø.14 | Ø.814E+ØØ | -3.34 | | |
| 16 | 1.81Ø | Ø.738 | Ø.134 | Ø.551E+Ø3 | 75.24 | Ø.9Ø9E+ØØ | -2.98 | | |
| 17 | 1.81Ø | 1.7Ø8 | Ø.Ø36 | Ø.777E+Ø3 | -Ø.62 | Ø.173E+ØØ | -28.52 | | |
| 18 | 1.81Ø | 1.134 | Ø.Ø75 | Ø.2Ø2E+Ø4 | 56.77 | Ø.687E+ØØ | -5.78 | | |
| 19 | 1.81Ø | 1.543 | Ø.Ø45 | Ø.164E+Ø4 | 11.73 | Ø.389E+ØØ | -22.69 | | |

USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

| | |
|---|---|
| TEST NO.: 322 | START DATE: 10-DEC-88 15:25:54 |
| TEST TYPE: EHP,RW ,120 PC | LOG DATE: 22-MAY-90 10:08:28 |
| MODEL NAME: WAGL | LWL: 4.69 FT |
| DISPLACEMENT: 31.3 LBS | LCG: 0.063 FT |
| WET SURFACE: 4.4 SQ FT | STIM: STUDS |
| PITCH GYRADIUS: 1.17 FT | WATER TEMP: 63.5(F) |
| SUBTEST VEL.: 1.777 KTS | WAVE DIRECTION: 180 DEG |
| FROUDE NO.: 0.244 | NO. OF PROPS: 0 |
| WAVE SENSOR TO AMID.: 2.00 FT | |



USNA HYDROMECHANICS LABORATORY
MODEL TEST RESULTS

| | |
|---|---|
| TEST NO.: 322 | START DATE: 19-DEC-89 15:25:54 |
| TEST TYPE: EHP,RW ,120 PC | LOG DATE: 22-MAY-90 10:08:28 |

| | |
|---|---|
| MODEL NAME: WAGL | LWL: 4.69 FT |
| DISPLACEMENT: 31.3 LBS | LCG: 0.063 FT |
| WET SURFACE: 4.4 SQ FT | STIM: STUDS |
| PITCH GYRADIUS: 1.17 FT | WATER TEMP: 63.5(F) |
| SUBTEST VEL.: 1.777 KTS | WAVE DIRECTION: 180 DEG |
| FROUDE NO.: 0.244 | NO. OF PROPS: 0 |
| WAVE SENSOR TO AMID.: 2.00 FT | |